APPENDIX 3

Groundwater Assessment

Haerses Road Quarry Groundwater Assessment

Prepared for Dixon Sands (Penrith) Pty Ltd

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Australian Groundwater Technologies

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Haerses Road Quarry Groundwater Assessment

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Prepared for

Dixon Sands (Penrith) Pty Ltd

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1 Introduction

1.1 Background

Dixon Sand (Penrith) Pty Ltd owns and operates a sand quarry off Haerses Road, Maroota, NSW. The quarry operates under an existing consent (DA 165-7-2006-5), which allows for the extraction of sand to a depth of 2 m above the wet weather groundwater elevation of the Maroota Tertiary Sands Groundwater Source (MTSGS). This depth was determined by the original Environmental Impact Statement (EIS) (ERM 2005).

Dixon Sands are seeking to modify the existing consent to allow the extraction of friable sandstone to the west of the current extraction area (within Lots 176/177/216). The proposed expansion falls outside the MTSGS and is situated above the Sydney Central Basin Groundwater Source (SCBGS)

The current area of extraction approved under the existing consent (DA 165-7-2006-5), and the proposed area of extraction being sought under this modification are presented on Figure 1.

The maximum depth of extraction in the area is constrained by the elevation of the *'wet weather groundwater elevation'* of the groundwater sources that underlie the site. These have been identified as the:

- MTSGS which comprises the Maroota Tertiary Sands unit and any weathered sandstone. This underlies the approved extraction area of the current consent.
- SCBGS which comprises the deeper Hawkesbury Sandstone Aquifer and underlies the proposed modification to the west of the current extraction area.

Defining the wet weather groundwater levels of each groundwater source utilised the sites existing groundwater monitoring network (Figure 1). For example, the depth of extraction in the approved extraction area was defined by the groundwater elevation of the existing H series observation bores (H2–14) that target the MTSGS. Whereas, the depth of extraction within the SCBGS (i.e. in the proposed extension area) was defined by the groundwater levels measured in the BH series observation bores (BH4 and BH5).

Since the original consent, policy changes have seen the introduction of the Greater Metropolitan Region Groundwater Sources Water Sharing Plan (WSP) (2011) and Aquifer Interference Policy (AIP) (2012). As part of the modification, the New South Wales Department of Primary Industries (DPI) requires evidence that the proposed modifications comply with the above mentioned plans. For this reason, AGT has assessed the modification against rules and criteria outlined in the WSP and AIP.

1.2 Objectives

The objectives of this assessment were to:

- Update the conceptual groundwater model, utilising additional drilling data and groundwater level monitoring data obtained since the original consent.
- Update the original groundwater assessment, including review of groundwater levels to determine the extraction depth limit for the new extraction area which overlays the SBCGS.
- Assess the quarry modifications against the Greater Metropolitan Region Water Sharing Plan (GMRWSP) and the Aquifer Interference Policy (AIP).
- Outline a strategy for groundwater monitoring and management that will ensure the modification will comply with the WSP and AIP.

1.3 Scope of Works

The scope of work is covered in the following sections and includes:

Section 2

- A description of the proposed modification (extension area).

Section 3

- Review previous groundwater EIS studies, drilling investigations and groundwater monitoring data and outline the new knowledge relevant to the proposed modification.

Section 4

- A description of the existing environment including groundwater levels and groundwater quality.

Section 5

- A description of the existing groundwater users including private bores and groundwater dependant ecosystems.
- A description of groundwater impacts to the groundwater sources and existing users from the proposed modification and
- Demonstration how the modification will comply with the AIP and WSP (see Section 9).

Section 6

- Confirmation of the wet weather groundwater elevation for the SCBGS and MTSGS, which was used to inform the maximum extraction depth of the proposed modification.

Section 7

- Outline groundwater monitoring and management which covers existing and proposed groundwater monitoring activities, presentation of baseline data for all aquifers since the original EIS,
- If required, outline of management and mitigation measures to protect groundwater quality and levels.

Section 8

- A description of the measures that would be implemented to avoid, minimise, (and if necessary), offset the potential impacts of the proposed modification, including proposals for adaptive management and/or contingency plans to manage any significant risks to the environment.

Section 9

- An assessment of potential impacts on the quality and quantity of groundwater resources in accordance with the AIP. The AIP came into effect in September 2012 and the modification has been assessed against the rules of this policy in terms of the impacts of the modification on the groundwater systems.
- An assessment of the modification against the rules and criteria of the Greater Metropolitan Region Groundwater Sources WSP.

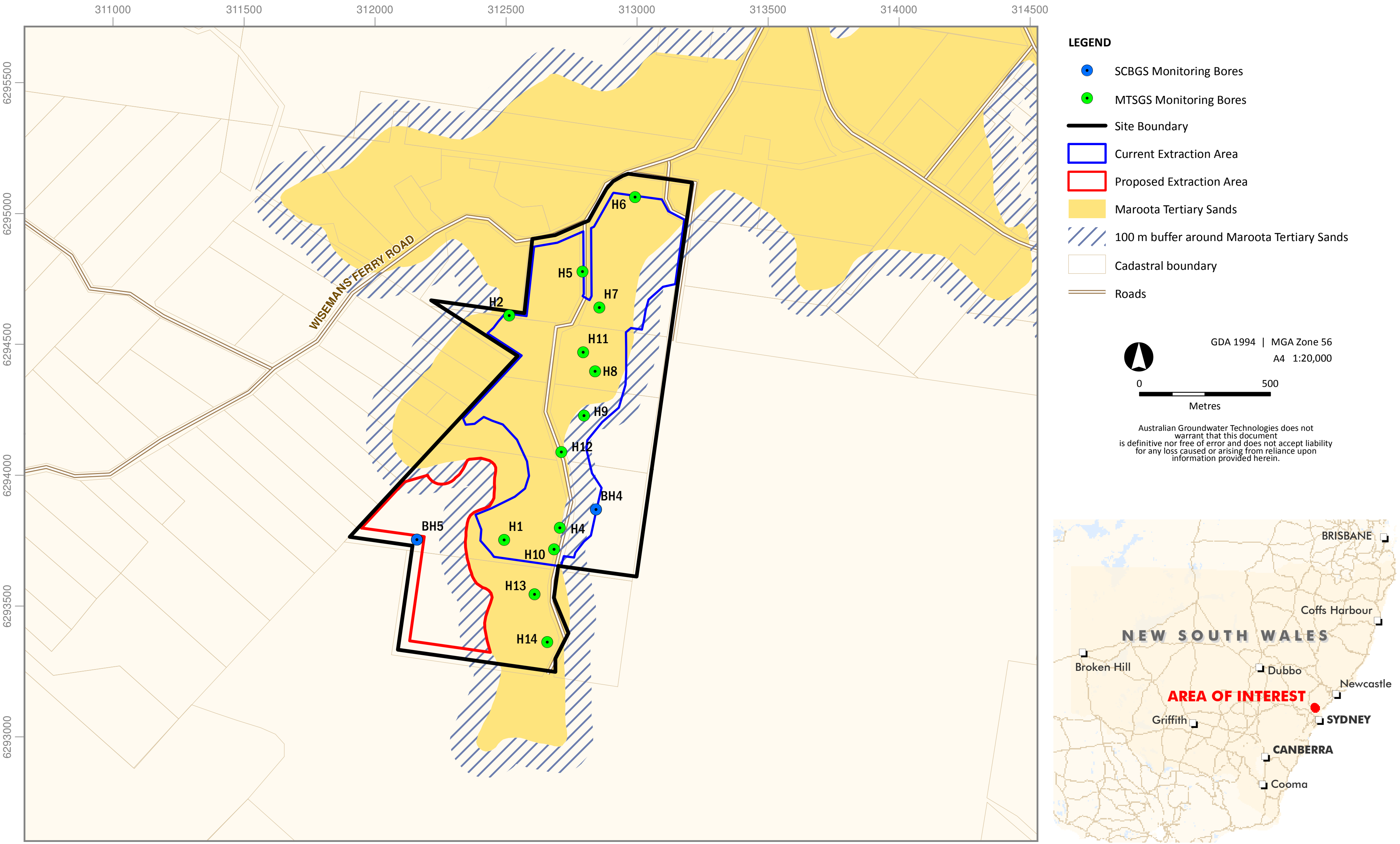

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Figure 1 | Current and proposed extraction areas including groundwater sources

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2 Proposed Expansion

2.1 Current Quarry Operations

The extent of the current extraction area is presented in Figure 2. The MTSGS is the commodity being extracted. The depth of the current quarrying operations is restricted to 2 metres above the maximum wet weather water table of the MTSGS.

2.2 Proposed Quarry Expansion

The extent of the proposed extraction area, including all necessary buffer zones, is presented in Figure 2. The SCBGS is the proposed commodity to be extracted. The depth of the proposed quarrying operations is restricted to 2 metres above the maximum wet weather water table of the SCBGS.

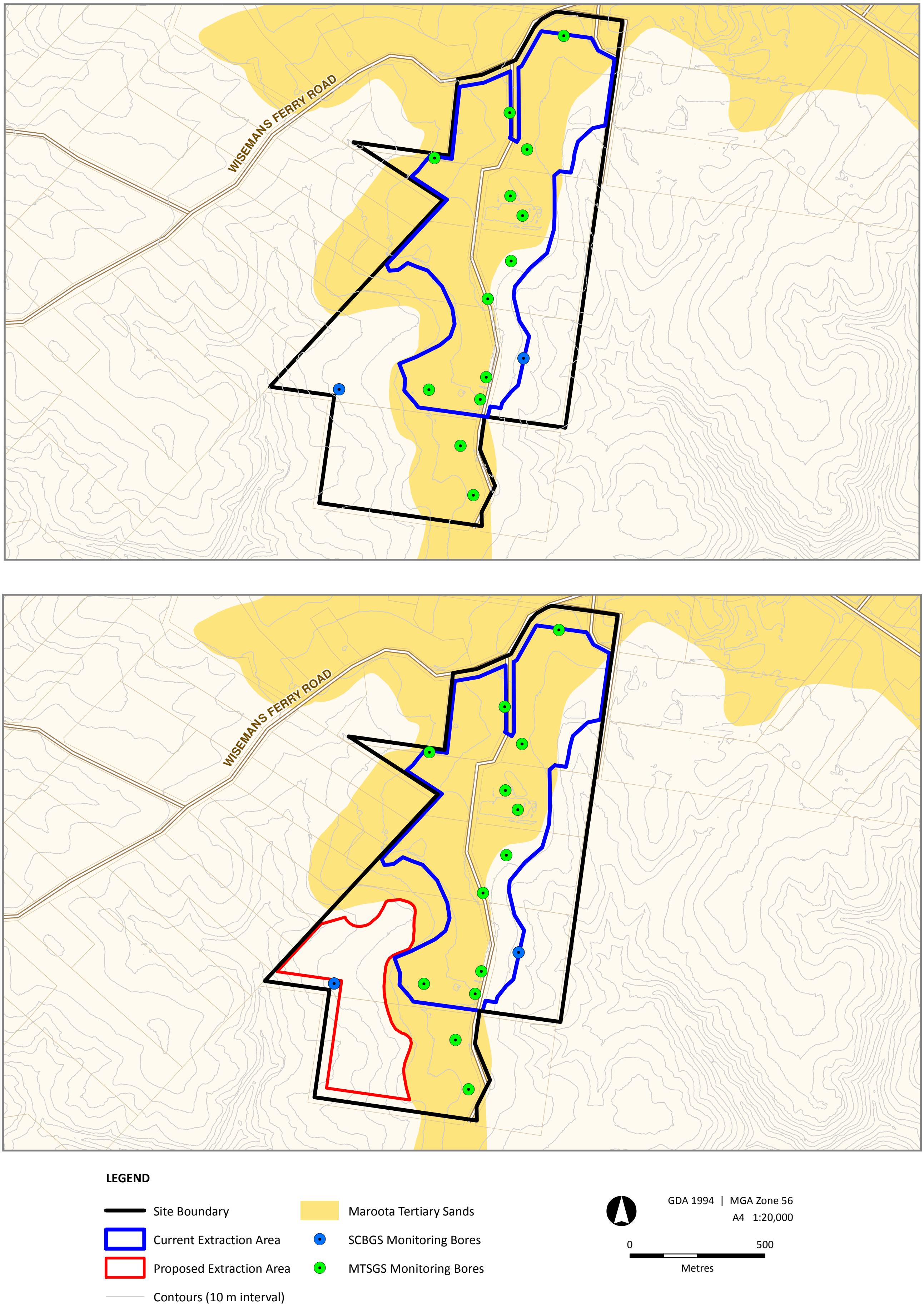

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Figure 2 | Current and proposed quarry operations including ground elevation contours

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1390-14-DAY_Hearses Rd EA\GIS\Maps\1390-DAY current&proposed operations-elevation contours.mxd

3 Previous Work

3.1 Overview

In the Maroota area there have been numerous groundwater assessments completed. The most relevant for this assessment include the Haerses Road EIS (ERM, 2005), Haerses Road Sand Quarry Environmental Monitoring Plan (EMP) (ERM, 2006) and the Groundwater Assessment for Dixon Sand Operations, Lot 1 and 2 DP547255 (RPS Aquaterra, 2012), which is located to the north of the Haerses Road Quarry.

3.2 Original EIS Assessment

In 2005, Environmental Resources Management (ERM) conducted an environmental impact assessment to support quarry extraction to 2 m above the 'wet weather' groundwater elevation for the MTSGS. The study concluded that the 'wet weather' groundwater elevation ranged between 171.5 to 185.7 mAHD, allowing quarrying to a maximum depth of between 173.5 and 187.7 mAHD (ERM 2005).

The assessment considered potential impacts including:

- reduced groundwater availability to users from water table lowering.
- groundwater contamination
- a reduction in groundwater quality to streams.

The following outlines the findings of the 2005 EIS. In addition, a provisional assessment has been conducted to highlight changes to the assessment for the proposed modification. This is discussed further in Section 8 (assessment against principles in the AIP and WSP).

3.2.1 Reduced groundwater availability to users / water table lowering

The original assessment concluded that because quarrying is restricted to two metres above the wet weather groundwater level, the groundwater surface will not be exposed at any time during quarrying. As such, a lowering of the groundwater levels as a result of evaporation losses is unlikely to occur.

In addition, rapid groundwater infiltration to the shallow aquifer occurs through the site's highly permeable soils, such that the quarrying of sand will not significantly increase the rate of recharge nor accelerate groundwater mounding through vertical infiltration.

3.2.2 Aquifer contamination

The original EIS identified the potential for aquifer contamination from fuel spillages principally from the operation of heavy machinery during quarry excavation. ERM (2005) assessed the risks from this activity as low provided adequate management strategies were in place i.e. appropriate fuel storages and implementation of a site management plan.

3.2.3 A reduction in groundwater quality to streams

Stripping of vegetation and topsoil for quarrying would typically cause recharge waters to be less acidic because of removal of humic material. The quarry area has been previously used for agriculture and the organic level of the soil has been altered. Therefore, the proposed quarry is unlikely to change the pH of the downstream environment.

3.3 Original Environmental Monitoring Plan

The existing groundwater monitoring network was established in 2005 and focused on monitoring the MTSGS via the H series monitoring bores (H1 to H10) (these were referred to a MW series in ERM 2006). The wet weather groundwater levels established during the EMP for the MTSGS are provided in Table 1. Further detail about the baseline monitoring data is provided in Section 4 of this report.

Table 1: Summary of the wet weather groundwater levels established during the EMP (Source: EMP 2006)

Monitoring Bore	Wet Weather Groundwater Level (mAHD)
H1	171.68
H2	178.75
H5	177.12
H6	180.68
H7	177.80
H8	184.69
H9	186.49
H10	175.72

3.4 SCBGS Drilling 2011

In 2011, two deeper monitoring bores (BH4 and BH5) were drilled to the east and west of the MTSGS and target the deeper SBCGS (Figure 1). The objective of these bores was to establish the wet weather elevation of the SBCGS to support this modification. The drilling logs for BH4 and BH5 are provided in Appendix A.

4 Hydrogeological Setting

4.1 Hydrogeology

The aquifers identified across the Maroota area incorporate the following Groundwater Sources:

- The Maroota Sands that together with the upper part of the Hawkesbury Sandstone (eluvial sands) constitute the regional water table aquifer. This unit forms the MTSGS.
- The Hawkesbury Sandstone, a regional fractured rock aquifer. The Hawkesbury Sandstone forms part of the SBCGS. The unit is competent (lithified) with secondary fracturing the predominant mechanism for groundwater flow.

The MTSGS is recharged by direct rainfall infiltration and is subject to seasonal rainfall variations and longer term climatic cycles. At the project site, water bore drilling has identified the MTSGS comprises of thin layers of gravel, thick sequences of clay, and interbedded clays and sands. These profiles are typical of palaeochannel sequences and represent the meandering nature of old river systems (Woodward and Clyde, 1999).

In the Weathered Profile of the Underlying Hawkesbury Sandstone small aquifer zones have developed in the eluvial sand, which comprises the leached and weathered profile of the Hawkesbury Sandstone. These zones often form perched aquifer systems above the deeper regional water level of the Hawkesbury Sandstone. In the majority of cases, these perched aquifer systems have limited resource value because, like the Maroota Sand, they have small aerial extent and storage. They act as temporary storage of groundwater prior to leakage to underlying aquifers.

The Hawkesbury Sandstone is generally an impermeable rock, due to the fine grained clayey matrix (largely kaolinite and illite) and large degree of grain cementation resulting from the development of secondary minerals in the interstitial spaces, such as secondary silica and siderite (iron carbonate). Although the rock has very little primary permeability, fracturing and jointing, where open and interconnected, provides secondary permeability and storativity.

In 2011, two monitoring bores were drilled to investigate the groundwater conditions to a depth of 65 m below ground level (bgl). Within the proposed extraction area on the western side of the MTSGS BH5 revealed hard sandstone from ground surface to the bottom of hole. Over the period of monitoring (2011-2016), groundwater elevations have ranged from 114.25 to 116.15 mAHD. On the eastern side of the MTSGS BH4 revealed sandstone to 10 m bgl, followed by unsaturated sands, clays and silts to 16 m bgl followed by hard sandstone of the SBCGS. The groundwater level in this bore was measured at 145.38 to 147.07 mAHD. The large difference in water level between these two bores is a reflection of the large difference in topographic elevation.

4.2 Groundwater Levels

4.2.1 Maroota Tertiary Sands Groundwater Source

The water level of the MTSGS has been monitored and recorded at the Haerses Road Quarry since 2005. Originally eight monitoring bores were used to monitor the water levels (see Table 1), however ongoing quarry operations have resulted in a number of the original bores being removed and new bores installed. The monitoring bores currently in operation are presented in Table 2 along with their maximum and average water levels recorded since monitoring began. The hydrographs for these bores are presented in Figure 3, and a groundwater contour map of the highest recorded groundwater elevation is presented in Figure 4. The cumulative deviation from mean monthly rainfall (Figure 3) demonstrates a strong relationship between rainfall and groundwater level within the MTSGS.

Table 2: Summary of monitoring bores targeting the MTSGS – Haerses Road Quarry

Bore ID	Maximum SWL (mAHD)	Maximum SWL Date	Average SWL (mAHD)
*H1	174.4	March 2005	172.15
H2	180.10	October 2013	178.46
*H4	188.95	December 2006	184.32
*H5	177.27	May 2005	177.13
H6	184.23	February 2016	182.39
H7	181.90	February 2016	179.69
*H8	187.37	June 2008	185.19
H9	187.99	May 2012	186.47
*H10	176.66	July 2007	176.09
*H11	186.01	November 2010	185.02
H12	183.50	April 2015	181.42
H13	173.00	May 2012	171.71
H14	176.50	February 2016	174.47

*Decommissioned/replaced

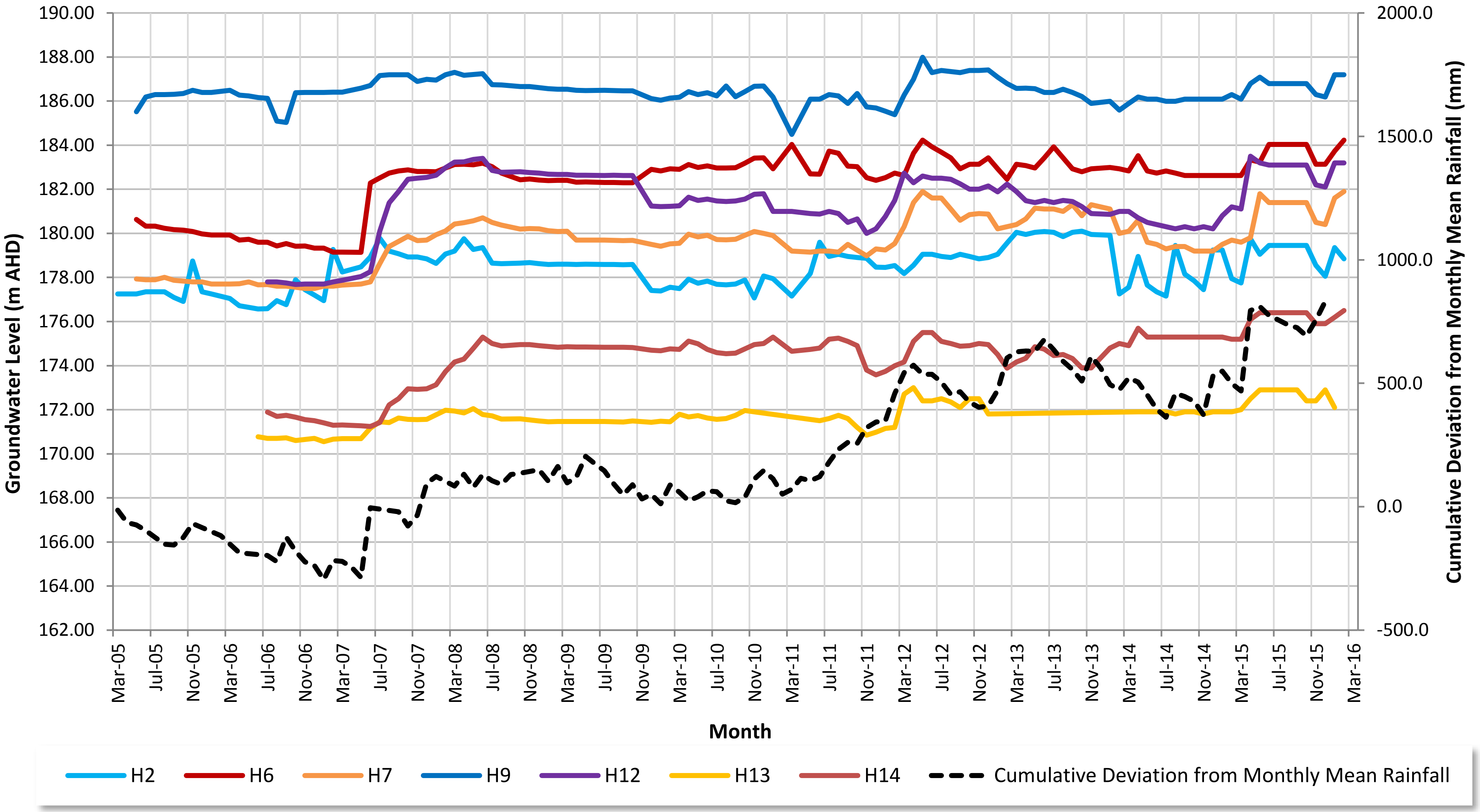
4.2.2 Sydney Central Basin Groundwater Source

The regional water table of the SCBGS has been monitored and recorded at the Haerses Road Quarry since 2011 via monitoring bores BH4 and BH5. A summary of the monitoring bores which includes their maximum and average water levels is presented in Table 3. The hydrographs for these bores are presented in Figure 5.

Table 3: Summary of monitoring bores targeting the SCBGS at the Haerses Road Quarry

Bore ID	Maximum SWL (mAHD)	Maximum SWL Date	Average SWL (mAHD)
BH4	147.07	March 2014	146.45
BH5	116.15	Jan 2016	114.81

Figure 3: Haerses Road long-term groundwater levels for the MTSGS H Series bores including the cumulative deviation from mean monthly rainfall



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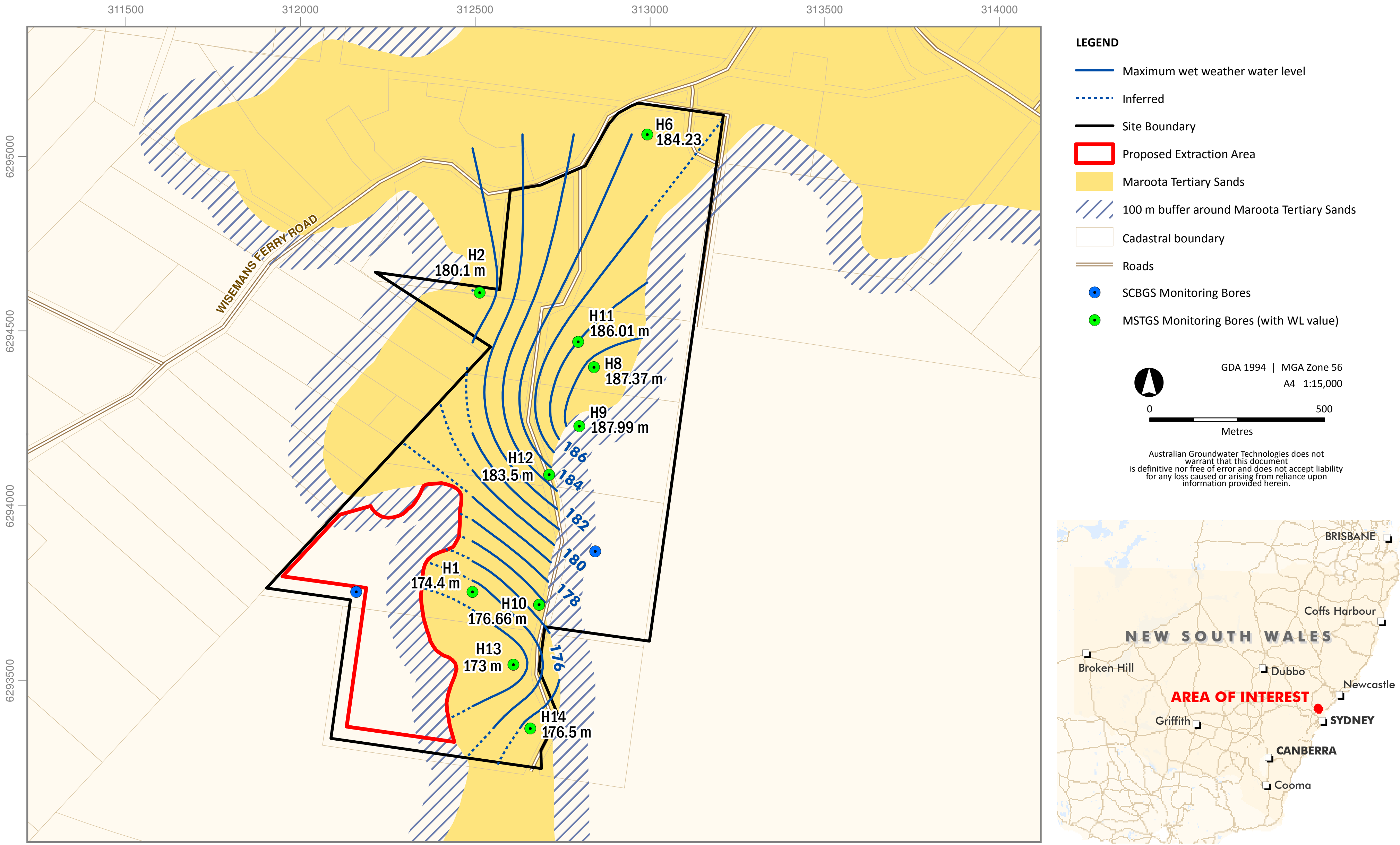

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Figure 4 | Maximum wet weather water level contour map for the MTSGS

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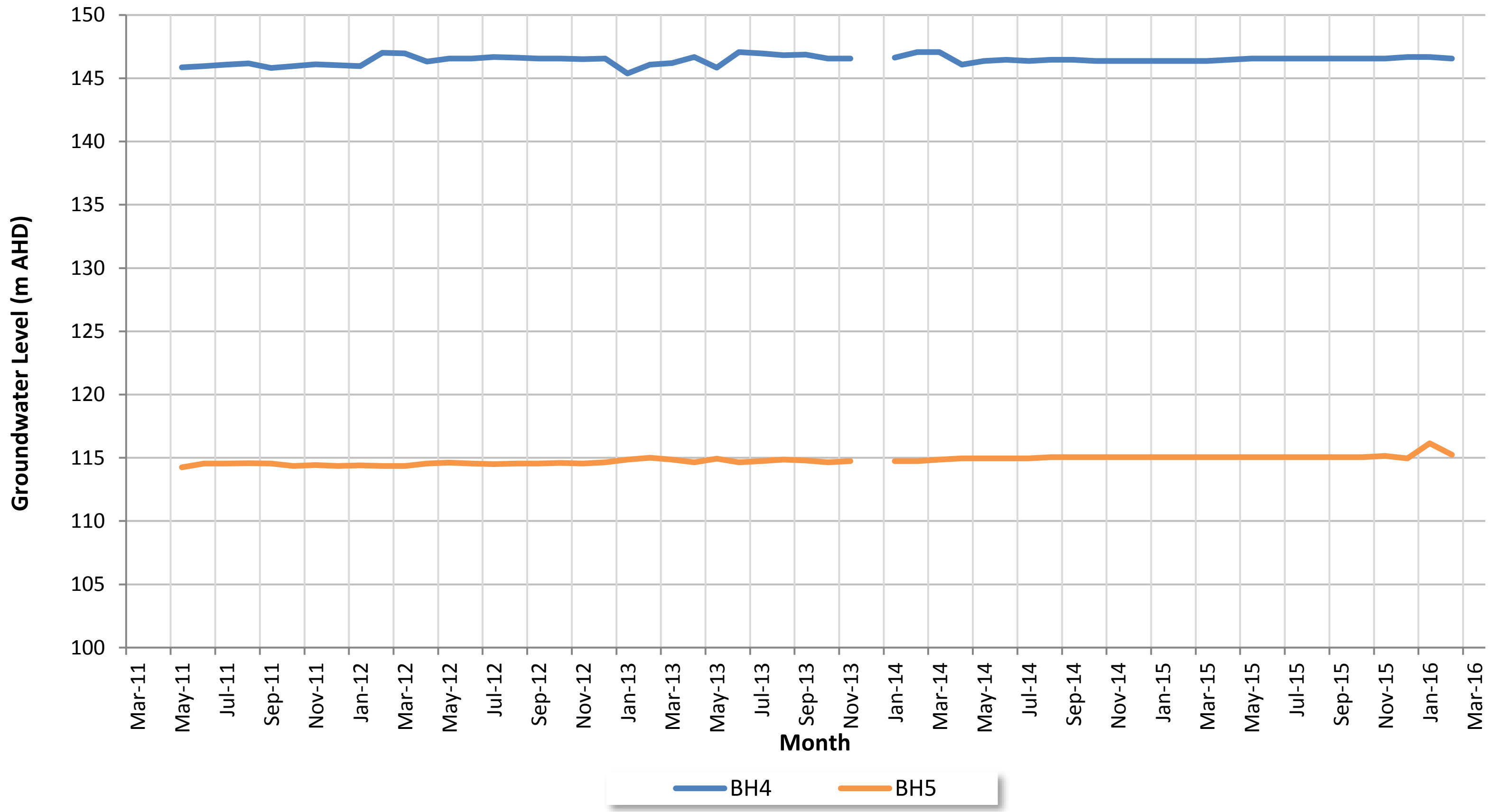
Figure 5: Haerses Road long term groundwater levels for the SCBGS BH Series bores



4.3 Water Quality

In accordance with the current development consent conditions, groundwater samples have been collected from each bore for analysis of the following parameters: Electrical Conductivity (EC), pH, Totals Suspended Solids (TSS) and Turbidity. A summary of the natural variation of groundwater quality is provided in Table 4 and summarises below.

- Groundwater salinity of the shallow and deep aquifers is very low, ranging from 51 to 435 µS/cm (~32 to 278 mg/L).
- pH ranges from 4.1 to 6.6, with deeper bores revealing higher average pH values (5.5) in comparison to the shallower bores (4.6).
- Groundwater turbidity and TSS was generally higher in the shallow bores than in the deeper bores.

As the groundwater salinity is <1,500 mg/L, the source is classified as a highly productive groundwater source under the criteria of the AIP.

Table 4: Water Quality for all bores on site

Bore	H2	H6	H7	H9	H12	H13	H14	BH4	BH5
Electrical Conductivity (µS/cm)									
Nov 10	64	187	426	152	207				
Jul 11	65	182	435	128	207	88	69	136	270
Jan 12	274	261	262	301	286			198	270
Jun 12	55	189	268	125	174	97	90	120	252
Dec 12	235	238	234	233	228	232	224	143	144
Jun 13	52	204	51	51	174	202	103	141	148
Feb 14	174	207	335	185	184		188	257	134
Jun 14	120	182	379	127	137	95		188	141
Dec 14	52	169	274	125	128	93		182	129
Jun 15	57	134	155	124	269	117	114	119	126
Dec 15	74	199	213	138	214			201	133
pH									
Nov 10	4.7	4.3	4.2	4.5	4.8				
Jul 11	4.3	4.4	4.4	4.8	4.8	4.6	4.9	5.6	4.9
Jan 12	4.6	4.2	4.1	4.4	4.7			5.3	4.6
Jun 12	4.9	4.4	4.4	5.1	5.8	4.7	4.9	5.7	4.7
Dec 12	4.7	4.6	4.9	4.7	4.6	4.5	4.5	4.6	4.6
Jun 13	4.6	5.9	4.6	4.6	4.7	4.7	4.8	6.6	6.3
Feb 14	4.3	4.4	4.4	5	4.9		4.9	5.3	6.2
Jun 14	4.4	4.4	4.3	4.7	4.8	4.6		6.1	6.4
Dec 14	4.2	4.1	4.1	4.6	4.2	4.4		4.8	5.3
Jun 15	4.7	4.3	4.4	4.6	4.8	4.6	5.2	5.7	6.2
Dec 15	4.6	4.4	4.4	5.3	4.7	6.8		5.6	5.8
Turbidity (NTU)									
Feb 14	55	1200	260	230	75		490	4	13
Jun 14	1400	840	720	160	8.5	400		17	27
Dec 14	60	7	75	27	2	24		9	15
Jun 15	45	15	24	36	26	810	50	9	29
Dec 15	100	290	32	25	4.3	75		7	17
TSS (mg/L)									
Feb 14	59	1580	288	266	91		583	18	7
Jun 14	1530	948	820	204	10	405		12	22
Dec 14	53	7	78	37	3	31		12	16
Jun 15	40	15	31	38	21	838	20	8	13
Dec 15	246	501	57	50	4	76		8	17

5 Groundwater Users

5.1 Existing Groundwater Users

There are a total of 40 existing bores within 2.5 km of the Haerses Road, 28 of which target the deep SCBGS with the remaining 12 targeting the shallow MTSGS. A summary of existing bores in the area is provided in Appendix B with their locations presented in Figure 6.

At the closest point there is one bore that targets the SCBGS (GW109927 – status unknown) located ~500 m west of the proposed quarry. It was drilled to a depth of 162 m and has a groundwater level of 74 mBGL. The nearest MTSGS bore (GW108385) is located ~150 m southeast of the proposed quarry and is drilled to a depth of 13 m.

5.2 Coastal Upland Swamp

There is a coastal upland swamp that has been identified to the north of the proposed extraction area and west of the current approved extraction area (map provided in Appendix C) by Umwelt (Umwelt, 2016). There is also a drainage feature that runs east to west through the swamp. The drainage feature is an ephemeral stream that only exists for a short period of time after rainfall events and is fed by an upstream dam.

The geomorphic development of the coastal upland swamps is driven by positive feedbacks that operate when there is significant excess of precipitation over evaporation. This, along with high run-on from catchments and low rates of percolation and run-off, promotes soil water logging. Drainage of the swamps is mainly via lateral seepage through the sediments with some possible very slow vertical percolation into the underlying poorly permeable bedrock. Channels, if present, are discontinuous and usually are very shallow and linking a series of deep pools at the downstream end of large valley-floor swamps (EPBC Act 1999).

It is proposed that a 60 m buffer zone be put in place around the swamp where extraction will not occur. The purpose of the buffer zone is to help protect and manage the national ecological community. The buffer zone is intended to act as a barrier to further direct disturbance. For instance, a buffer zone may help to protect the ecological community from altered water flows, pollution and other threats (EPBC Act 1999).

There is an additional much smaller area of Coastal Upland Swamp on the eastern edge of the proposed extraction area. This area of Coastal Upland Swamp would be impacted by extraction within the 100 metre buffer of the MTSGS if this was approved by the NSW Department of Environment and Planning (DPE) following the monitoring process.

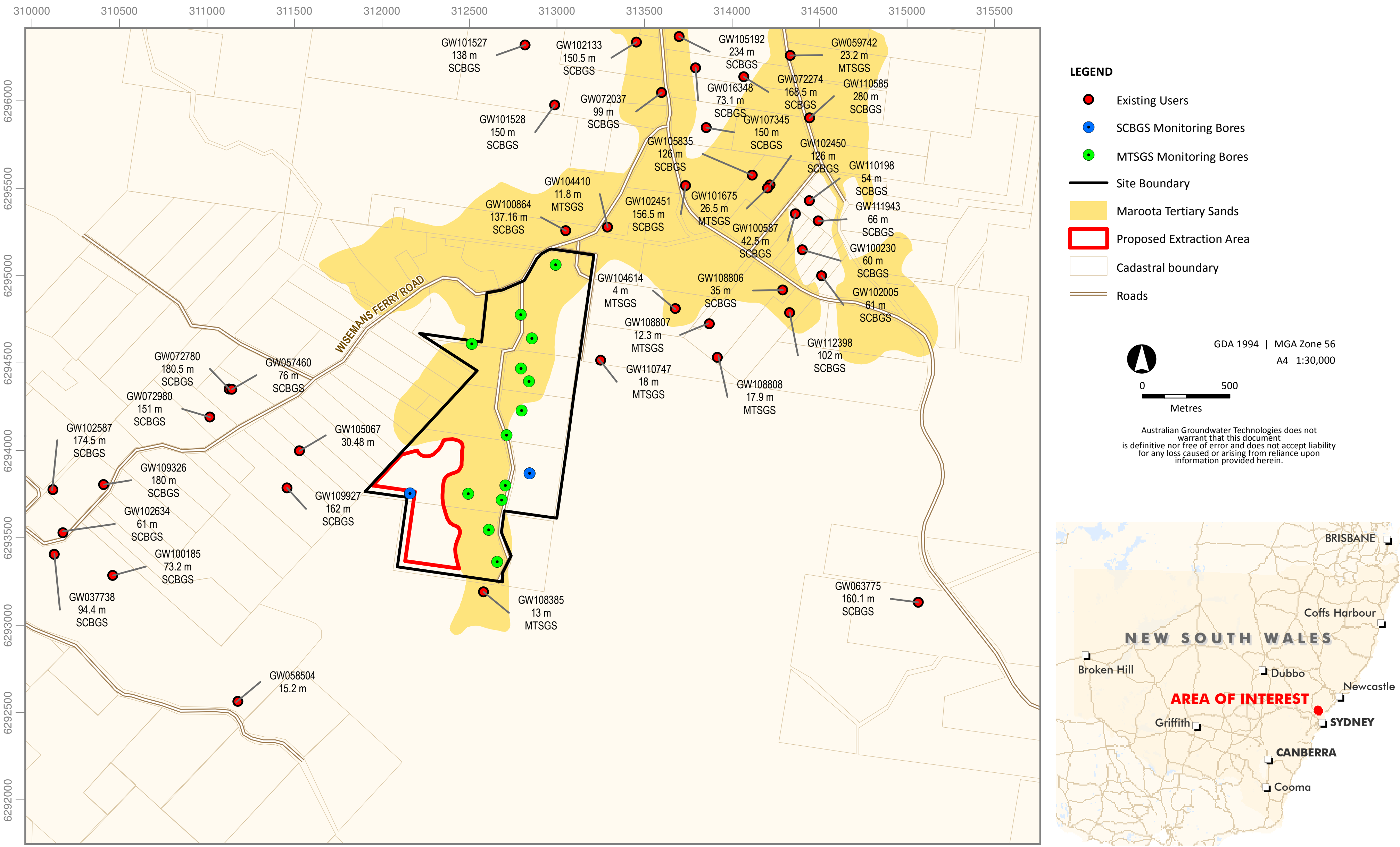


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Figure 6 | Existing groundwater users including the H and BH well series

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6 Quarry Extension: Wet Weather Groundwater Elevation

6.1 Wet Weather Groundwater Elevation

Groundwater monitoring data has been used to establish groundwater elevations for the MTSGS (since 2005) and the SBSGS (since 2011).

The highest recorded water level measured in each bore was used to develop a maximum extraction depth map (Figure 7). The maximum extraction depth contours represent an elevation of 2 m above the wet weather groundwater level sources.

The wet weather elevation of the SBCGS (and extraction depth) is lower than the wet weather elevation of the MTSGS, which is perched some 40 m above the regional aquifer of the SBCGS. Groundwater seepages from the MTSGS will be prevented by the creation of a 100 m buffer from the western boundary of the MTSGS. The proposed buffer zone is shown on Figure 7 and on the cross section of the site (Figure 8).

The buffer zone occupies the low permeability Hawkesbury sandstone. Groundwater monitoring of the MTSGS, including two proposed addition bore locations (Figure 9), would be ongoing during extraction operations outside of the buffer zone to determine any potential changes or impacts to the MTSGS. No extraction would be undertaken within the buffer zone until groundwater monitoring results show that quarrying can be undertaken in this area without impacting on the MTSGS. The decision to commence quarrying in this area will be undertaken in consultation with DPI Water and with the approval of the DPE. Any extraction that occurs within this buffer zone should remain at least 2 m above the shallow water table of the H series bores which target the MTSGS. The maximum extraction depth within the buffer zone, based on the contours produced on Figure 7 is 176 to 180 mAHD.

The maximum extraction depth within the proposed extraction area, based on the wet weather elevation of BH4 and BH5 is between 118.15 and 133.5 mAHD (as shown in Figure 8).

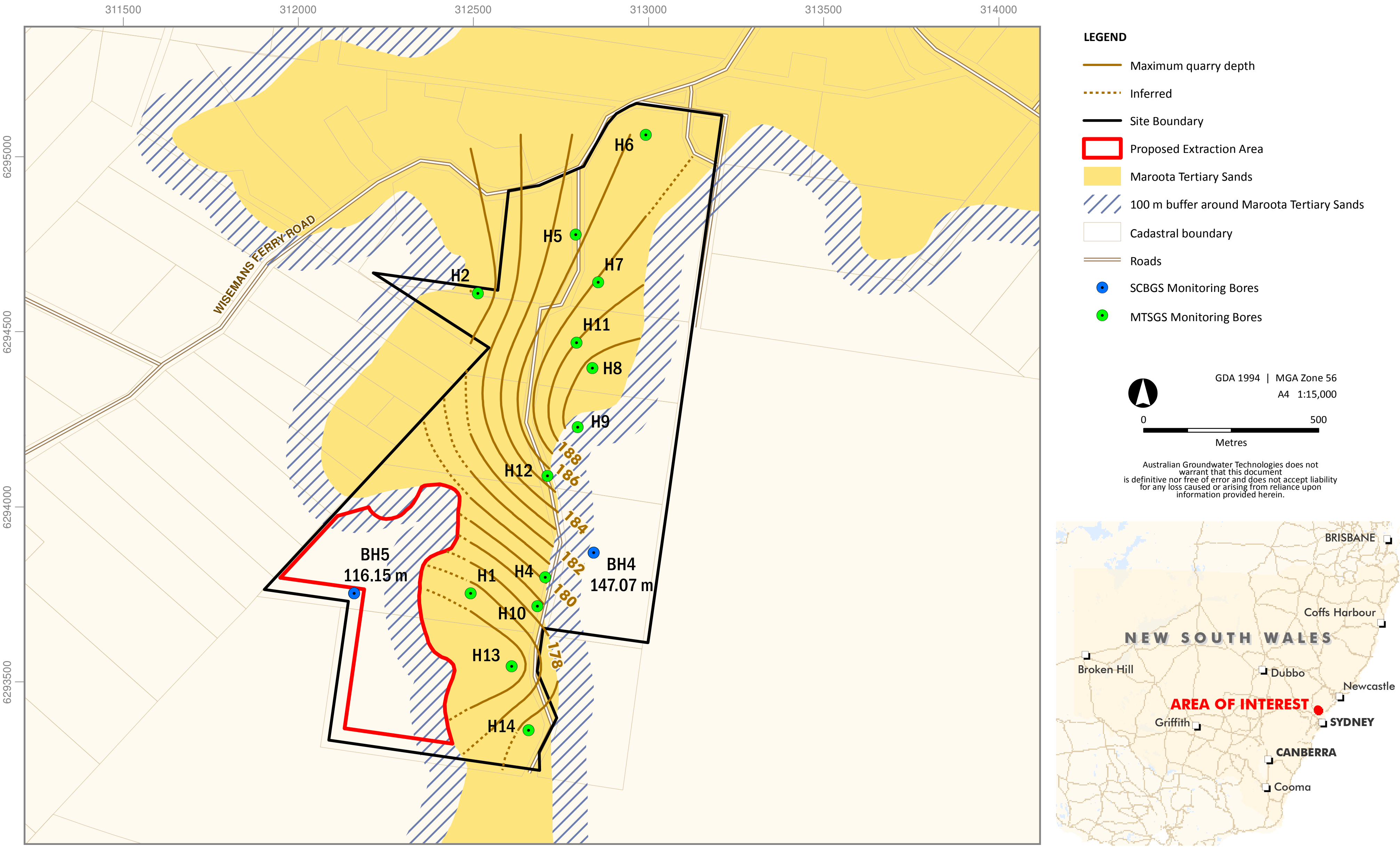

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Figure 7 | Maximum quarry depth for the MTSGS based on the wet weather water level *(2 m above wet weather water table)*

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1390-14-DAY_Hearses Rd EA\GIS\Maps\1390-DAY max quarry depth.mxd

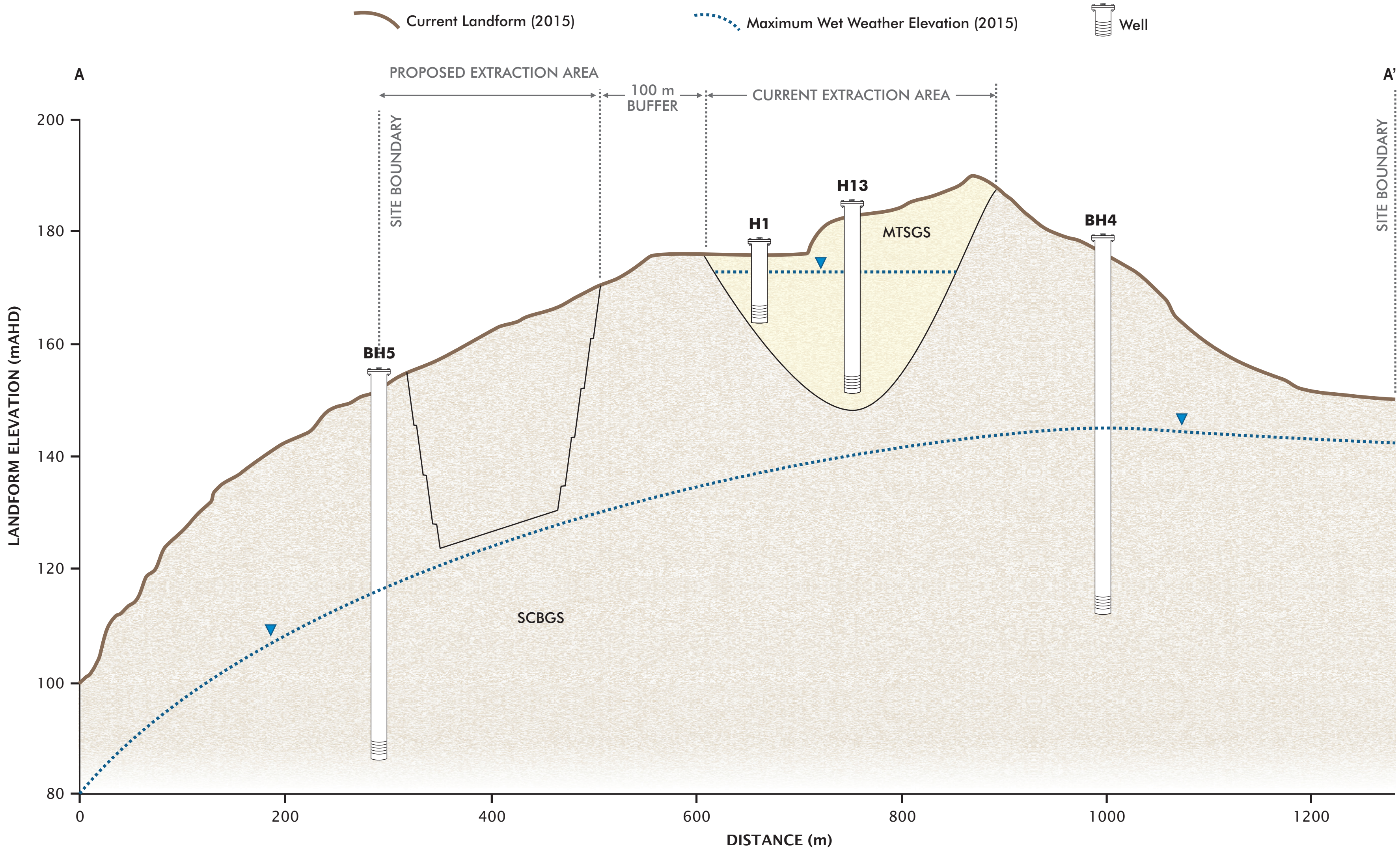

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Figure 8 |Cross Section between BH4 and BH5

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7 Groundwater Monitoring and Management

7.1 Existing Groundwater Monitoring Program

The locations of the groundwater monitoring bores at Haerses Road are presented in Figure 6 and are summarised in Table 2.

A baseline groundwater monitoring programme for the Haerses Road site has been active since 2005 and is ongoing. The monitoring network was expanded in 2011 with the installation of the deeper BH monitoring bore series that target the SBCGS. The Haerses Road monitoring network includes nine monitoring bores (see Sections 3 and 4).

7.2 Proposed Groundwater Monitoring Program

Although quarrying at Haerses Road Quarry will not exceed 2 m above the wet weather groundwater level of the SBCGS or the MTSGS, monitoring will be continued for the life of the project to detect any unforeseen groundwater level or quality impacts, including any impacts to existing groundwater users.

Prior to any extraction within the 100 metre buffer zone of the MTSGS, groundwater monitoring results during the period of extraction immediately adjacent to the buffer zone would be reviewed and discussed with DPI Water to identify any potential changes or impacts. Extraction within the 100 metre buffer zone would not proceed until DPE provide approval to do so.

Monitoring of the existing network should continue, however two additional monitoring bores are recommended on the western margin of the MTSGS. The bores will be used to detect any unforeseen groundwater responses over the life of the quarrying. The proposed locations for the new monitoring bores are shown on Figure 9.

The proposed monitoring program for an approved operation is summarised in Table 5, and has been designed to detect changes in groundwater levels, groundwater quality, or to indicate an abnormal condition in response to quarrying. Key aspects include:

- Water quality sampling from groundwater across the project area on a biannual basis.
- Monitoring and assessment of groundwater inflows and quality to the open cut quarry operations, in the unlikely event that groundwater inflows occur.
- Monitoring groundwater levels in the MTSGS and SBCGS.

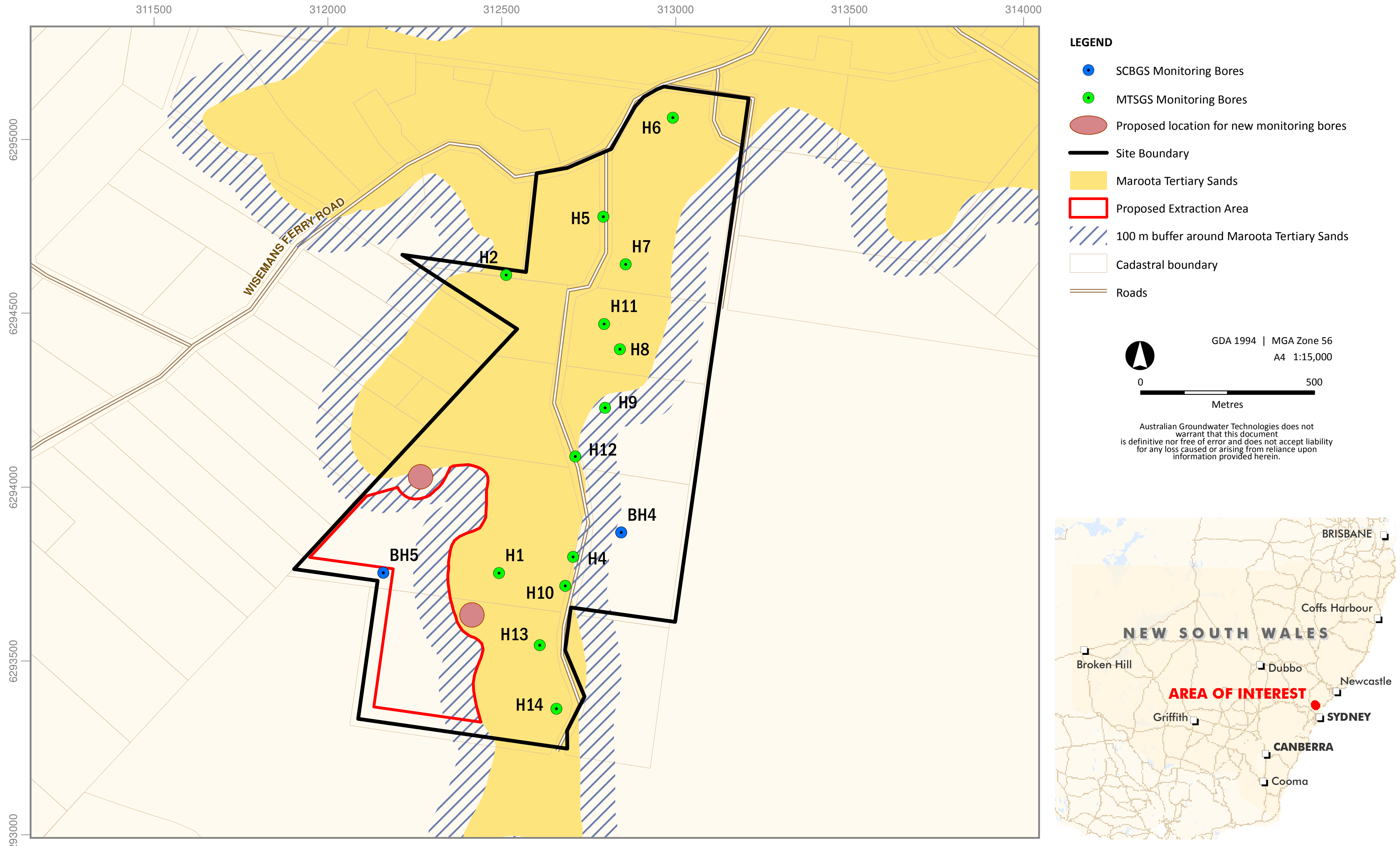

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Figure 9 | Current monitoring network including proposed locations for new monitoring bores

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Table 5: Proposed groundwater monitoring program

Pre-quarrying	Purpose	Weekly	Monthly	Bi-annual
MTSGS – H2,6,7,9,12,14 SCBGS – BH4,5	To obtain baseline, pre-quarrying conditions for the two aquifers		Water level	
	Provide the foundation for establishing trigger values for investigation			Field Parameters EC, TSS, pH, Turbidity
	Obtain natural variation of regional groundwater level, such that depth of quarrying can be determined		Water level	
During quarrying				
MTSGS – H2,6,7,9,12,14 SCBGS – BH4,5	Ensure quarrying is maintained 2 m above the groundwater levels of the MTSGS and SBCGS		Water level	
	Monitor any unforeseen water quality impacts, ensuring that there is no change in overall beneficial use category >40 m from site			Field Parameters EC, TSS, pH, Turbidity
	Monitor unforeseen regional impacts, ensure there are no WL/WQ impacts to neighbouring private bores		Water level	Field Parameters EC, TSS, pH, Turbidity
	Ongoing compliance with the WSP and AIP	No pit seepages are expected, but undertake volumetric measurements in the unlikely event that measurable seepages occur	No pit seepages are expected, but sample for water quality in the unlikely event that measurable seepages occur	
Post quarrying				
MTSGS – H2,6,7,9,12,14 SCBGS – BH4,5	Monitoring of post-quarrying water level and quality impacts and ensuring ongoing compliance with the WSP and AIP			Water level & Field Parameters

8 Management of Groundwater Impacts

8.1 Groundwater Management Strategy

The strategy for groundwater management is to prevent groundwater inflows from the MTSGS and SBCGS to the quarry, and preservation of pre-quarrying groundwater quality. It involves maintaining the depth of quarrying to an elevation which is at least 2 m above the ‘wet weather’ groundwater elevation and creation of a 100 m buffer zone as discussed in Section 6.

Groundwater components assessed to be at risk have been previously assessed by ERM (2005) and summarised in Section 3.2 of this report. Mitigation measures have been proposed for each potential impact including predicted and unpredicted impacts. As such the groundwater monitoring program specifically deals with:

- A mechanism for ensuring the project is compliant with the rules of the WSP and AIP (DPI, 2012).
- Unforeseen impacts on groundwater levels on neighbouring properties and on any users of groundwater that target the MTSGS or SBCGS.
- Unforeseen impacts on groundwater quality (including impacts from chemical storage areas).
- Periodic monitoring for local and regional impacts of the quarry on groundwater levels and quality during the project and on a reduced basis for at least five years post quarrying.

Information gained from the monitoring program has been used to determine a maximum pit extraction depth of between 118.15 and 133.5 mAHD outside of the 100 m buffer zone and to a depth of 176 to 180 mAHD inside the buffer zone. This will ensure the pit floor remains at least 2 m above the ‘wet weather’ groundwater level, thereby mitigating any drawdown impact to the SBCGS and MTSGS.

Ongoing groundwater monitoring serves to notify changes to the groundwater, quality or unforeseen discharges into the pit. Monitoring is necessary to indicate that abnormal conditions relating to quarrying have developed, as well as compliance with the rules of the WSP and AIP.

A Trigger Action Response Plan (TARP) for groundwater will be developed to focus upon appropriate trigger and response actions for the management or mitigation of impacts. The baseline monitoring program that is in place will be used to establish the triggers, which will consider the level of impact and trigger an appropriate response. The fundamental means of determining the magnitude of any impact and the need for further monitoring and / or remedial actions is based upon the impact assessment criteria detailed in Table 6. The responses (actions) documented in the Table are proposed to ensure the timely and adequate management of impacts outside of the established trigger levels.

Table 6: Trigger Action and Response Plan

Impact	Observation	Strategy for Mitigation	Monitoring	Monitoring Action	Response
Groundwater level	Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the water sharing plan.	Baseline GWL data has been used to ensure depth of quarrying remains above the MTSGS and SCBGS. Regular review of monitoring data to ensure quarrying is maintained above the elevation of the regional water table. For quarrying of the SBCGS, a 100 m buffer zone has been proposed along the western margin of the MTSGS to ensure the perched aquifer is not impacted.	**MTSGS:** H series bores **SBCGS** BH series bores **Buffer Zone:** New monitoring bores to be installed within buffer zone (see Figure 9)	**Water level**: If water level monitoring indicates increasing trends or confirmed pit inflows, increase monitoring frequency to weekly to establish trend.	Investigate potential contributing factors: -Confirm trends or anomalies by repeating water level or quality sampling as required -Compare exceedance with climatic conditions -Engage a hydrogeologist to undertake a preliminary investigation and report on any identified changes. Where investigations determine that impacts are the result of Quarry operations or may potentially impact on adjacent bores or surface water users implement Section 8.2 of this report, which may include: Modify mine plan or
Groundwater quality	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.	Ensure all spillages are contained, diversion of dirty water into settling ponds, maintenance of machinery to be undertaken in work shop areas. Water quality monitoring of the pit will be undertaken as a first line of defence to detect & control the risk of groundwater contamination.	In-pit surface expressions	**Water Quality**: Repeat sampling of bore and in pit water to confirm contamination event.	
Groundwater users	Reported decrease in yield or GWL outside of climatic variations. Reported decrease in water quality parameter outside of baseline variation.	Baseline GWL data has been used to ensure depth of quarrying remains above the MTSGS and SCBGS. Regular review of monitoring data to ensure quarrying is maintained above the elevation of the regional water table.		**Water level**: Increase monitoring frequency to weekly to establish trend.	

Pit inflows	Observed seepages from pit wall	Any groundwater inflows should be metered in isolation of any other inputs such as rainfall runoff. Regular review of monitoring data to ensure quarrying is maintained above the elevation of the SCBGS. Monitoring of water quality in pit will be undertaken as a first line of defence to control the risk of groundwater contamination. **Buffer zone monitoring** If any seepage of groundwater is observed from the buffer area into the pit and that water is sufficient to measure, Dixon Sands will measure and record the volume of water pumped from the pit using a flow meter on the pump to show how much water is removed.		**Water level**: Increase monitoring of bores to weekly to establish trend. **Water quality:** obtain comprehensive analysis from pit seepages. **Volume:** weekly record of pit seepages.	obtain groundwater licence to offset impact.

8.2 Quarry Responsible Impacts Procedure

Where investigations detailed in the TARP determine that groundwater impacts are the result of quarry operations or the quarry may potentially impact on adjacent bores, the following procedure will be conducted:

- Inform landholders adjacent to streams and / or private bore owners, and the NSW Office of Water of preliminary investigation outcomes as appropriate.
- Undertake a detailed investigation and assess possible mitigation measures in consultation with the landowner and the NSW Office of Water.
- If deemed necessary prepare and implement a site mitigation/action plan to the satisfaction of the Department of Primary Industries (DPI), in consultation with the landowner and the NSW Office of Water.
- Conduct a review of results from the follow up investigation.

Further, the responses referred to above include, but are not limited to:

- Results of preliminary investigation reported within one week of completion.
- Commence preparation of detailed investigation including assessment of possible mitigation measures immediately.
- Commence preparation of mitigation / action within one week of the need being identified.

8.3 Notification of Significant Impact

Where a significant, confirmed impact to the environment or private landowner has occurred according to the TARPs, relevant agencies will be contacted immediately.

9 Assessment against the AIP and WSP

9.1 Aquifer Interference Policy (2012)

As detailed in this report, the depth of the development will not extend to the depth of the groundwater level for the SCBGS. For this reason, aquifer interference will not occur and the project is compliant with the rules of the AIP. For clarity however, all of the rules and requirements stipulated in the AIP have been summarised in Table 7. with reasons why rules are satisfied. Table 8 provides additional data to support the assessment of "minimal impact" as stipulated in the AIP (see page 26 of AIP, 2012).

Table 7: Minimal impact considerations for aquifer interference activities

	Highly Productive Groundwater Sources					
	Water Table	**Summary of impact and monitoring**	**Water Pressure**	**Summary of impact and monitoring**	**Water Quality**	**Summary of impact and monitoring**
1. Alluvial Water Sources	1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2 m decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan then appropriate studies (c) will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2 m decline cumulatively at any water supply work, then make good provisions should apply.	**Mitigation Measure:** Quarrying will be maintained 2 m above the wet weather regional groundwater level for the two aquifers. There will be no groundwater extraction or pit inflows during or post quarrying activities from the regional water table. This will mitigate any drawdown impact to high priority GDE's or culturally significant assets. **Monitoring**: Groundwater monitoring will be conducted onsite via the monitoring bore network. These bores will monitor groundwater level trends and detect any unforeseen impacts including detection of impacts > 40 m from the site.	1. A cumulative pressure head decline of not more than 40% of the "post water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	**Mitigation Measure:** Quarrying will be maintained 2 m above the wet weather regional groundwater level for the two aquifers. For this reason, this principle is not applicable. **Monitoring**: Deep monitoring bores are already on site that monitor the SCBGS. These bores will be monitored and maintained during quarry operations to detect any unforeseen groundwater impacts. This will be in addition to the shallow monitoring bore that targets the MTSGS.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.	**Mitigation Measure:** Quarrying will be maintained 2 m above the wet weather regional groundwater level for the two aquifers. There are no water quality impacts as a result of the project. There are no GDE or Water supply works identified in the greater area that could be impacted. **Monitoring**: Suitably constructed monitoring bores will be maintained on to detect any unforeseen groundwater quality impacts.

Table 8: Summary of AIP requirements

Requirement	Summary of compliance	Reference of compliance
Establishment of baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area potentially affected by the activity, any existing monitoring bores and any new monitoring bores that may be required under an authorisation issued under the *Mining Act 1992* or the *Petroleum (Onshore) Act 1991.*	Baseline groundwater and quality data has been captured since 2005 for shallow and deep bores, over a range of climatic variations.	Section 4 of this report; (ERM 2005)
A strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans. For example, returning water of an acceptable quality to the affected water source during periods when flows are at levels below which water users are not permitted to pump.	Project is in accordance with the rules of the WSP, in particular meets the criteria stipulated for both the MTSGS and The Sydney Basin Central Groundwater Source.	Section 4 and 9 of this report.
Details of potential water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right. Consideration will need to be given to any relevant distance restriction requirements that may be specified in any relevant water sharing plan or any remediation measures to address these impacts.	No impact to existing users as the MTSGS will not be intercepted as part of quarrying activities nor will the Sydney Basin Central Groundwater Source.	Section 4 and 9 of this report.
Details of potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources.	No impact to existing users as the MTSGS will not be intercepted as part of quarrying activities nor will the Sydney Basin Central Groundwater Source.	Section 4 and 9 of this report.
Details of potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems.	Groundwater will not be intercepted as part of quarrying operations, and for this reason impacts to GDE's are will not occur.	ERM 2005
Details of potential for increased saline or contaminated water inflows to aquifers and highly connected river systems.	Mitigation measures for contamination are in place.	Section 8-9, Table 6 of this report
Details of the potential to cause or enhance hydraulic connection between aquifers.	Quarrying will be above the MSTGS, therefore there is no opportunity for hydraulic connection to the underlying Sydney Basin Central Groundwater Source.	Section 4 of this report
Details of the potential for river bank instability, or high wall instability or failure to occur.	Quarrying will not be carried out near any significant river or drainage line.	ERM 2005
Details of the method for disposing of extracted water (in the case of coal seam gas activities).	N/A	N/A

9.2 Compliance with Water Sharing Plan

The MTSGS and the SBCGS are the gazetted groundwater resources underlying the development area. Geological mapping conducted by the Geological Survey of NSW (Etheridge, 1980 as cited in Woodward-Clyde, 1999) confirms that the proposed development is encapsulated by outcropping Maroota Sands and Hawkesbury Sandstone (see Figure 1). For this reason, rules in the WSP have been considered for the MTSGS and the SCBGS and are detailed in Tables 9 and 10 respectively.

Table 9: Summary spreadsheet of WSP rules and compliance for the MTSGS

Access Rules	Relevance for this Development	Reason why rule is not applicable
Granting of access licenses may be considered for a listed number of activities	Not applicable	- The proposed work modifications do not seek an access license because the regional Maroota Sands aquifer will not be intercepted. Excavations from quarrying will extend to a maximum depth of 189.99 mAHD, 2 m above the approved 'wet weather' groundwater elevation (187.99 mAHD) and a buffer zone will be put in place between the modification and MTSGS to prevent seepage losses.
Rules for managing water allocation accounts		
Carryover	Not applicable	- No access license is being sought therefore amendments to license conditions are not required, - The Maroota Tertiary Sands Groundwater Source will not be intercepted during site operations.
Rules for Managing Access Licenses		
Managing surface and groundwater connectivity	Not applicable	- The existing pit is >40 m from the high bank of any named river or creek. - The nearest groundwater seepage points are over 1 km to the south-west and north-east of the quarry site.
Rules for granting or amending water supply works approvals		
To minimise interference with neighbouring water supply networks	Not applicable	The regional Maroota Sands aquifer will not be intercepted and therefore interference with neighbouring bores cannot occur.
To protect bores located near contamination	Not applicable	- No access licence is being sought, - The development does not intercept or abstract groundwater and therefore will not impact hydraulic gradients, or facilitate the mobilization of any contamination in the vicinity, - The development remains entirely in the unsaturated zone, - No areas of contamination have been identified within 500 m of the proposed operation
To protect water quality	Not applicable	- The pit floor will be at least 2 m above the wet weather water level of the MTSGS and therefore does not intercept groundwater, - The development remains in the unsaturated zone and therefore cannot initiate saline intrusion to the aquifer.

Access Rules	Relevance for this Development	Reason why rule is not applicable
To protect bores located near sensitive environmental areas	Not applicable	- No groundwater supply works are being carried out as part of the development, - No interception of the groundwater source will take place. Groundwater will not be intercepted or taken during quarrying either through pumping or inflows from open voids, - The development remains entirely above the ‘wet weather’ groundwater elevation and will not impact on any discharges to / from sensitive environmental areas.
To protect groundwater dependent culturally significant sites	Not applicable	- No groundwater supply works are being carried out as part of the development, - No interception of the groundwater source will take place. Groundwater will not be intercepted or taken during quarrying either through pumping or inflows from open voids, - The development remains entirely above the ‘wet weather’ groundwater elevation and will not impact on any discharges to / from sensitive environmental areas.
Rules for replacement groundwater supply works	Not applicable	- Groundwater replacement works are not being conducted. The proposed work modifications relate specifically to the quarry plan, extraction methods and the estimated mine life.
Rules for the use of water supply works approvals		
To manage bores located near contaminated sites	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose. - No contaminated site exists within 500 m of the proposed operation
To manage the use of bores within restricted distances	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose.
To manage the impacts of extraction	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose.
Limits to the availability of water		
Available water determinations (AWD’s)	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose.

Table 10: Summary spreadsheet of WSP rules and compliance for the SCBGS

Access Rules	Relevance for this Development	Reason why rule is not applicable
Granting of access licenses may be considered for a listed number of activities	Not applicable	- The proposed work modifications do not seek an access license because the SCBGS aquifer will not be intercepted. Excavations from quarrying will extend to a maximum depth of 2 m above the approved 'wet weather' groundwater elevation.
Rules for managing water allocation accounts		
Carryover	Not applicable	- No access license is being sought therefore amendments to license conditions are not required, - The Sydney Central Basin Groundwater Source will not be intercepted during site operations.
Rules for Managing Access Licenses		
Managing surface and groundwater connectivity	Not applicable	- The existing pit is >40 m from the high bank of any named river or creek. - The nearest groundwater seepage points are over 1 km to the south-west and north-east of the quarry site.
Rules for granting or amending water supply works approvals		
To minimise interference with neighbouring water supply networks	Not applicable	The SCBGS aquifer will not be intercepted and therefore interference with neighbouring bores cannot occur.
To protect bores located near contamination	Not applicable	- No access licence is being sought, - The development does not intercept or abstract groundwater and therefore will not impact hydraulic gradients, or facilitate the mobilization of any contamination in the vicinity, - The development remains entirely in the unsaturated zone, - No areas of contamination have been identified within 500 m of the proposed operation.
To protect water quality	Not applicable	- The pit floor will be at least 2 m above the wet weather water level of the SCBGS and therefore does not intercept groundwater. - The development remains in the unsaturated zone and therefore cannot initiate saline intrusion to the aquifer.

Access Rules	Relevance for this Development	Reason why rule is not applicable
To protect bores located near sensitive environmental areas	Not applicable	- No groundwater supply works are being carried out as part of the development, - No interception of the groundwater source will take place. Groundwater will not be intercepted or taken during quarrying either through pumping or inflows from open voids, - The development remains entirely above the 'wet weather' groundwater elevation and will not impact on any discharges to / from sensitive environmental areas.
To protect groundwater dependent culturally significant sites	Not applicable	- No groundwater supply works are being carried out as part of the development, - No interception of the groundwater source will take place. Groundwater will not be intercepted or taken during quarrying either through pumping or inflows from open voids, - The development remains entirely above the 'wet weather' groundwater elevation and will not impact on any discharges to / from sensitive environmental areas.
Rules for replacement groundwater supply works	Not applicable	- Groundwater replacement works are not being conducted. The proposed work modifications relate specifically to the quarry plan, extraction methods and the estimated mine life.
Rules for the use of water supply works approvals		
To manage bores located near contaminated sites	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose, - No contaminated site exists within 500 m of the proposed operation.
To manage the use of bores within restricted distances	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose.
To manage the impacts of extraction	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose.
Limits to the availability of water		
Available water determinations (AWD's)	Not applicable	- The proposed work modification does not involve groundwater extraction or interception of gazetted groundwater sources for any purpose.

10 References

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Environmental Resources Management (ERM), 2005. *Proposed Sand Quarry at Haerses Road, Maroota Environmental Impact Statement.* June 2005, Report 0020185EIS

Environmental Resources Management (ERM), 2006. *Haerses Road Sand Quarry Environmental Monitoring Program*. July 2006, Report 0049170EMPfinal

Etheridge, L.H., 1980. *Geological Investigation and Resource Assessment of the Maroota Tertiary Alluvial Deposit*. Geological Survey of New South Wales, Department of Mineral Resources. Report GS1980/201

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RPS Aquaterra, 2012. *Groundwater Assessment for Dixon Sand Operations, Lot 1 and 2 DP547255 Maroota NSW*. August 2012, Report S95/021D

Umwelt, 2016. Haerses Road Quarry Modification – Biodiversity Assessment Report

Woodward-Clyde, 1999. *Lots 1 and 2, DP228308, Lot 2, DP312327, Maroota, Development Application. Groundwater Impact Assessment*

Appendix A – Bore logs

COMPOSITE WELL LOG

Well No: BH4

RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

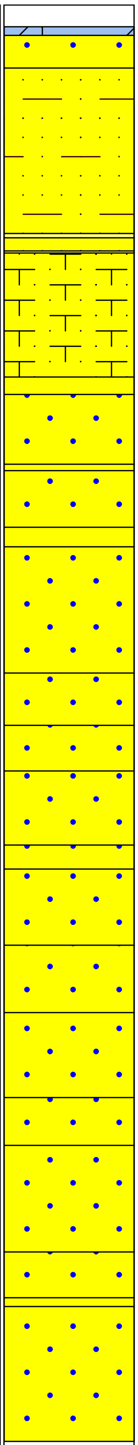
Client: Dixon Sand (Penrith) Pty Ltd **Project:** S95

Commenced:		**Method:**	Rotary Air	**Area:**	Maroota
Completed:	01/11/2010	**Fluid:**		**East:**	312843.05
Drilled:	Terratest	**Bit Record:**		**North:**	6293869.05
Logged By:				**Collar (RL):**	177.07

Static Water Level: 30.51 **Date:** 15/11/2010

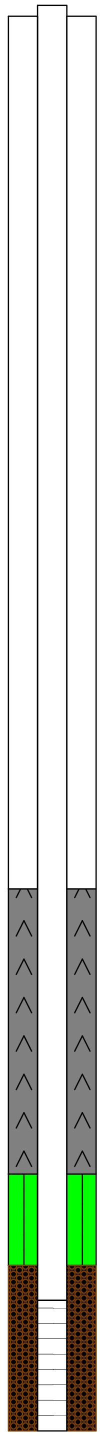
Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes

Depth scale (mbgl): 0, 10, 20, 30, 40, 50, 60, 70



Lithological Description:

- Topsoil: Top Soil Sand
- Sandstone: Red sandstone, hard
- Sand and Silt: Fine sandstone/siltstone white
- Clay: Clay band, moist
- Sand and Silt: fine sandstone/siltstone white/red
- Clay: Clay band
- Silty Sand: Fine silty sandstone white
- Sandstone: Sandstone yellow
- Sandstone: Sandstone white (18.4 to 18.6 m hard)
- Sandstone: Sandstone some clay
- Sandstone: Sandstone gray
- Sandstone: Clayey sandstone gray (22 to 25 m approx. water 40 l/m)
- Sandstone: Sandstone gray
- Sandstone: Sandstone gray brown, ironstone gravels
- Sandstone: Sandstone/Shale, some ironstone
- Sandstone: Sandstone, some gravels
- Sandstone: Sandstone yellow
- Sandstone: Sandstone, some shale and ironstone gravels
- Sandstone: Sandstone brown, some ironstone
- Sandstone: Sandstone gray
- Sandstone: Sandstone, some shale
- Sandstone: Sandstone, gray
- Sandstone: Sandstone/Shale
- Sandstone: Sandstone, some clay
- Sandstone: Sandstone gray. Water 58.3 l/m



Well Completion Notes:

- Blank PVC (0 to 40.1m)
- Grout (40.1m to 53.2m)
- Bentonite (53.2m to 57.4m)
- Gravel Pack (57.4m to 65m)
- Screen (59m to 65m (EOH))

RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

COMPOSITE WELL LOG

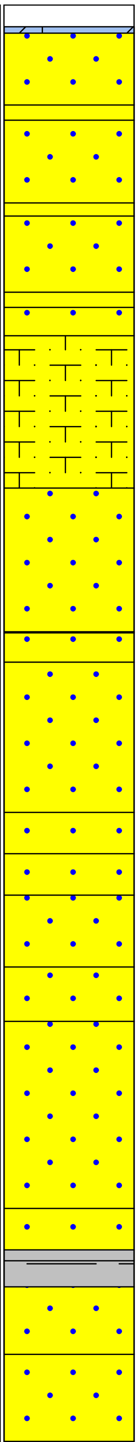
Well No: BH5

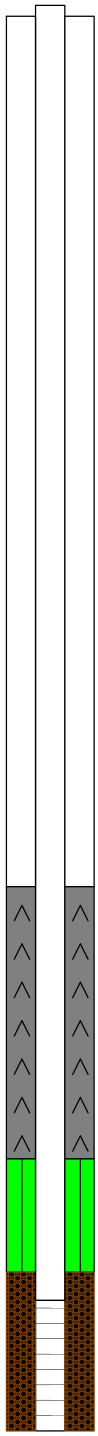
Client: Dixon Sand (Penrith) Pty Ltd **Project:** S95

Commenced:	**Method:** Rotary Air	**Area:** Maroota
Completed: 03/11/2010	**Fluid:**	**East:** 312159.4
Drilled: Terratest	**Bit Record:**	**North:** 6293753.96
Logged By:		**Collar (RL):** 152.75

Static Water Level: 37.78 **Date:** 15/11/2010

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0	Sandstone		Topsoil: Top soil sand			
			Sandstone: Sandstone white			
			Sandstone: Sandstone red			
			Sandstone: Sandstone white, 6.2 m small clay band			
10			Sandstone: Sandstone orange			
			Sandstone: Fine sandstone white			
			Sandstone: Sandstone orange			
			Sandstone: Fine sandstone white			
	Silt/Sandstone		Silty Sand: Silty fine sandstone, 15.9 m clay band, moist.			
20	Sandstone		Sandstone: fine sandstone gray			Blank PVC (0 to 40m)
			Ironstone: Ironstone, hard			
	Sandstone		Sandstone: Silty sandstone gray, fine			
30			Sandstone: Sandstone brown			
			Sandstone: Sandstone gray			
40			Sandstone: Sandstone yellow			
			Sandstone: Sandstone brown, ironstone gravels. 42.8 m water 10 l/m			
			Sandstone: Sandstone brown			Grout (40m to 52.5m)
50			Sandstone: Sandstone brown, ironstone layers			
	Sand		Sandstone: Sandstone/Shale			Bentonite (52.5m to 57.7m)
	Shale		Shale: Shale			
60	Sandstone		Shale: Shale, some iron stone gravels			Gravel Pack (57.7m to 65m)
	Sandstone		Sandstone: Sandstone/Shale, some Ironstone. 58.7 m water 6 l/m			
			Sandstone: Sandstone gray			Screen (59m to 65m (EOH))
70						





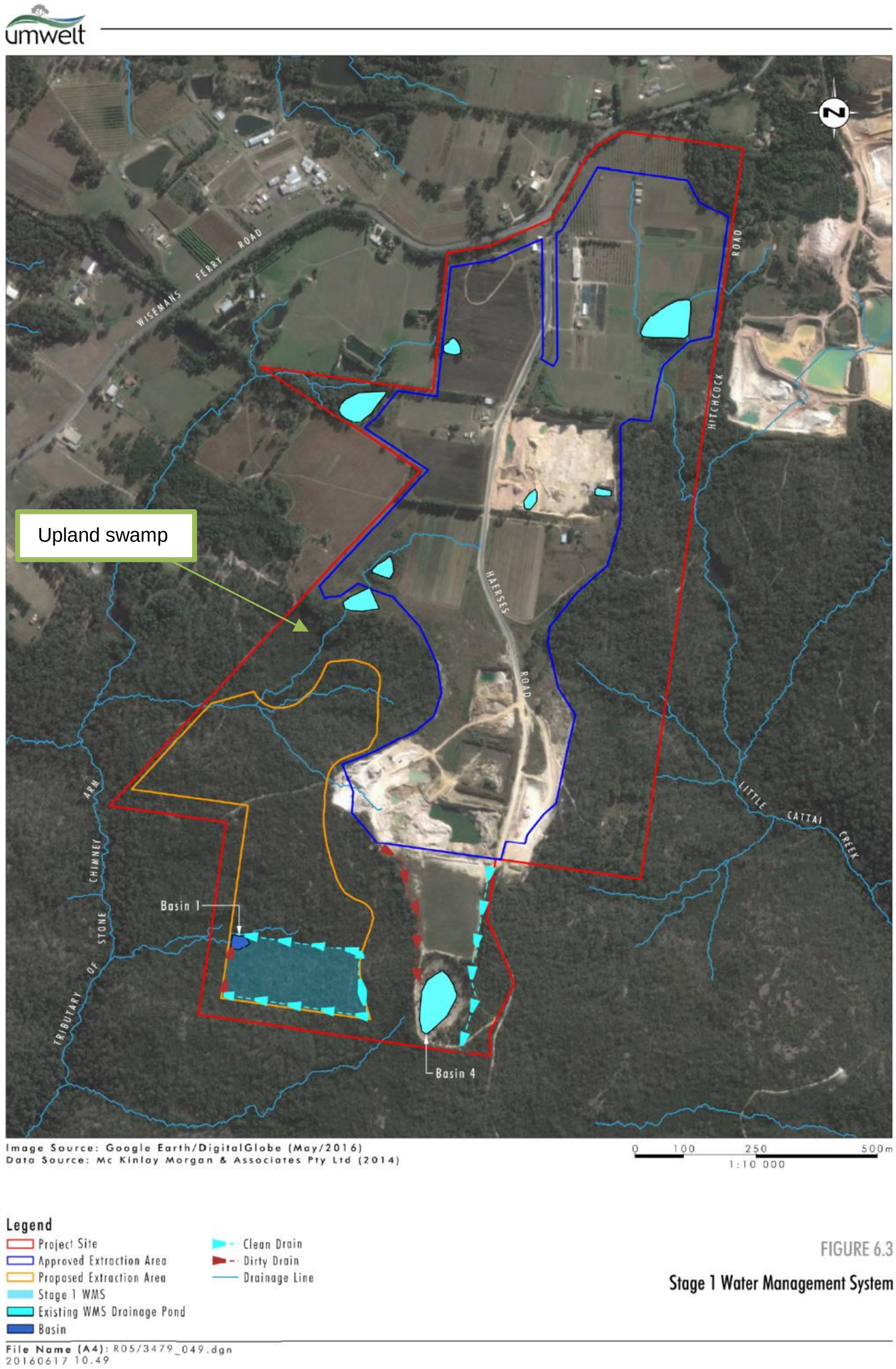
Appendix B – Private Bores

Bore ID	Easting	Northing	Depth (m)	SWL (mBGL)	Water Level Date	Targeted Aquifer	Aquifer Code
GW072980	311016	6294189	151 m			Hawkesbury Sandstone	SCBGS
GW072780	311127	6294350	180.5 m			Hawkesbury Sandstone	SCBGS
GW057460	311142	6294348	76 m			Hawkesbury Sandstone	SCBGS
GW105067	311528	6293997	30.48 m	26.212	1/01/1984	Perched	PRCH
GW109927	311457	6293784	162 m	74	16/12/2008	Hawkesbury Sandstone	SCBGS
GW108385	312580	6293190	13 m			Maroota Sands	MTSGS
GW108384	312543	6293400	19 m			Maroota Sands	MTSGS
GW108383	312613	6293885	17 m			Maroota Sands	MTSGS
GW106934	312503	6293888	15.8 m			Maroota Sands	MTSGS
GW108382	312586	6294155	14 m			Maroota Sands	MTSGS
GW109635	312838	6294207	15.7 m			Maroota Sands	MTSGS
GW108386	312681	6294291	17 m			Maroota Sands	MTSGS
GW106936	312894	6294451	15.6 m			Maroota Sands	MTSGS
GW110747	313250	6294515	18 m	4.1	14/04/2009	Maroota Sands	MTSGS
GW106937	312896	6294658	15.3 m			Maroota Sands	MTSGS
GW106938	312899	6294752	15.3 m			Maroota Sands	MTSGS
GW100649	313211	6924830	22.8 m			Maroota Sands	MTSGS
GW104614	313676	6294811	4 m			Maroota Sands	MTSGS
GW108807	313871	6294723	12.3 m			Maroota Sands	MTSGS
GW108808	313916	6294531	17.9 m			Maroota Sands	MTSGS
GW112398	314329	6294786	102 m			Hawkesbury Sandstone	SCBGS
GW108806	314290	6294918	35 m			Hawkesbury Sandstone	SCBGS
GW102005	314512	6294999	61 m	18	31/03/1998	Hawkesbury Sandstone	SCBGS

Bore ID	Easting	Northing	Depth (m)	SWL (mBGL)	Water Level Date	Targeted Aquifer	Aquifer Code
GW100230	314402	6295147	60 m	29	18/06/1993	Hawkesbury Sandstone	SCBGS
GW111943	314493	6295313	66 m	30	4/12/2012	Hawkesbury Sandstone	SCBGS
GW100587	314362	6295353	42.5 m	14	24/11/1992	Hawkesbury Sandstone	SCBGS
GW110198	314442	6295428	54 m	28	3/07/2009	Hawkesbury Sandstone	SCBGS
GW105835	314116	6295574	126 m	17.2	6/07/1999	Hawkesbury Sandstone	SCBGS
GW102450	314218	6295518	126 m			Hawkesbury Sandstone	SCBGS
GW101675	314203	6295500	26.5 m			Maroota Sands	MTSGS
GW102451	313735	6295514	156.5 m			Hawkesbury Sandstone	SCBGS
GW104410	313289	6295277	11.8 m	10.57	6/03/1998	Maroota Sands	MTSGS
GW100864	313050	6295256	137.16 m			Hawkesbury Sandstone	SCBGS
GW063775	315065	6293130	160.1 m			Hawkesbury Sandstone	SCBGS
GW109326	310409	6293804	180 m	82	11/09/2008	Hawkesbury Sandstone	SCBGS
GW102587	310120	6293774	174.5 m			Hawkesbury Sandstone	SCBGS
GW102634	310177	6293528	61 m			Hawkesbury Sandstone	SCBGS
GW037738	310127	6293404	94.4 m			Hawkesbury Sandstone	SCBGS
GW100185	310462	6293284	73.2 m			Hawkesbury Sandstone	SCBGS
GW058504	311177	6292562	15.2 m			Perched	PRCH
GW107345	313853	6295846	150 m	55	24/08/2004	Hawkesbury Sandstone	SCBGS
GW110585	314443	6295902	280 m	74	15/09/2005	Hawkesbury Sandstone	SCBGS
GW072274	314067	6296137	168.5 m			Hawkesbury Sandstone	SCBGS
GW059742	314333	6296259	23.2 m			Maroota Sands	MTSGS
GW103148	314520	6296617	60 m	11	23/03/2000	Hawkesbury Sandstone	SCBGS
GW053898	314327	6296567	31 m			Maroota Sands	MTSGS
GW104460	314078	6296500	96 m			Hawkesbury Sandstone	SCBGS
GW105192	313698	6296366	234 m	46	27/03/2003	Hawkesbury Sandstone	SCBGS

Bore ID	Easting	Northing	Depth (m)	SWL (mBGL)	Water Level Date	Targeted Aquifer	Aquifer Code
GW016348	313792	6296187	73.1 m			Hawkesbury Sandstone	SCBGS
GW072037	313598	6296047	99 m			Hawkesbury Sandstone	SCBGS
GW101528	312987	6295975	150 m	20.58	4/03/1998	Hawkesbury Sandstone	SCBGS
GW102133	313454	6296335	150.5 m	77	11/03/1999	Hawkesbury Sandstone	SCBGS
GW108133	313484	6296427	150.6 m	58	9/04/2004	Hawkesbury Sandstone	SCBGS
GW034628	313477	6296458	91.4 m			Hawkesbury Sandstone	SCBGS
GW048741	313603	6296615	30 m			Perched	PRCH
GW101527	312818	6296319	138 m	35.36	6/03/1998	Hawkesbury Sandstone	SCBGS
GW105046	313074	6296497	25 m	5	1/01/2002	Maroota Sands	MTSGS
GW103993	313159	6296827	30 m	18	1/11/1998	Maroota Sands	MTSGS
GW103992	312937	6296628	25 m	17	1/11/1998	Maroota Sands	MTSGS

Appendix C – Upland Swamp



APPENDIX 4

Traffic and Transport Assessment

ACN: 164611652
Suite 10, 265 King Street
Newcastle NSW 2300
Ph: (02) 4925 7795
admin@secasolution.com.au

21 September 2016

P0300 Dixon Quarry

Umwelt (Australia) Pty Limited
75 York Street
Teralba, NSW 2284

Attn: Lachlan Sweeney

Dear Lachlan,

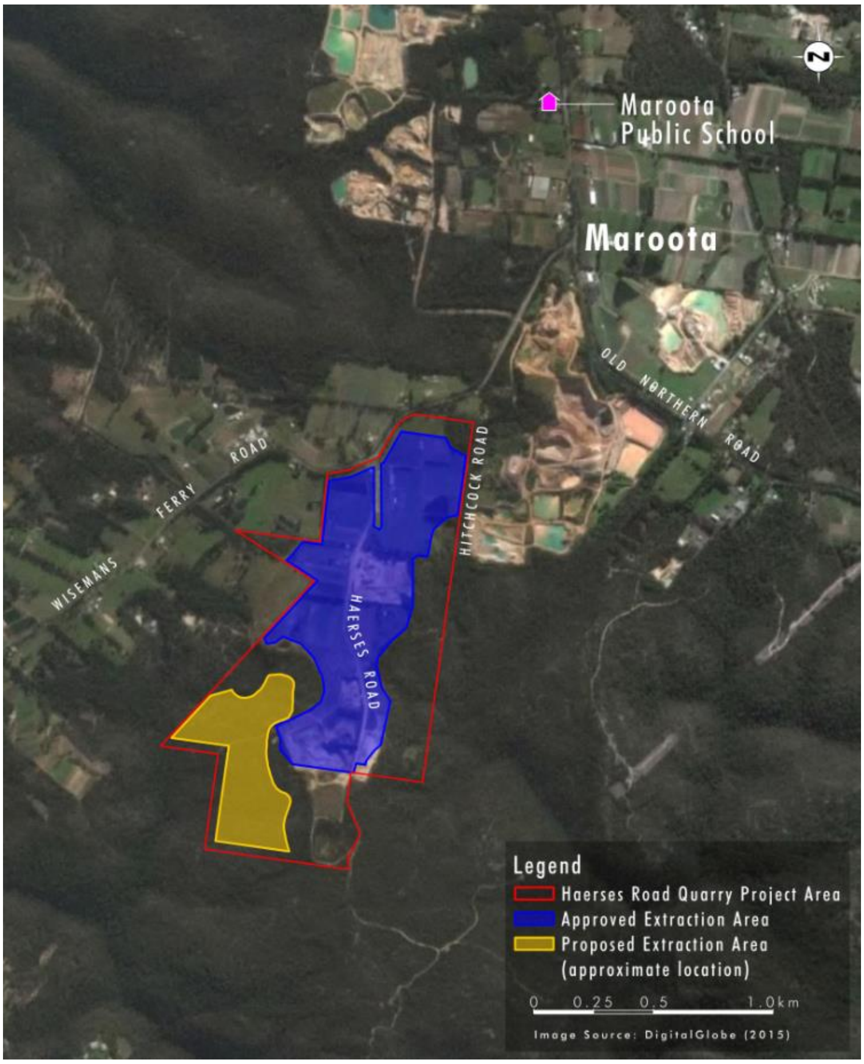
Proposed additional extraction area, Dixon Sand Quarry, Haerses Road, Maroota, NSW
Traffic Impact Assessment

Further to our recent discussions, we have completed our site investigation of the proposed additional extraction area of the Dixon Sand quarry at Haerses Road, Maroota. We have reviewed the access location and have reviewed the project description. The subject site is located within the general locality of Maroota with the key access route being south along the Old Northern Road towards Sydney.

This traffic impact assessment has been prepared in accordance with the Austroads Guidelines and Section 2.3 of the RMS Guide to Traffic Generating Developments. Section 2.3 of the RMS Guide to Traffic Generating Developments provides a structure for reporting, covering the key issues to be addressed in determining the impact of traffic associated with a development. The Guide indicates that using this format and checklist will ensure that the most significant matters associated with a Development Application are considered by the road authority, be they the RMS or Council.

The report has also taken into consideration The Hills Hornsby Development Control Plan 2013 which makes reference to the Sydney Regional Environmental Plan No 9--Extractive Industry (No 2--1995) - Reg 1.

The location of the site is shown below.



The items identified in Section 2.3 of the RMS Guide to Traffic Generating Developments are addressed below.

Item	Response
Existing Situation	
2.1.1 Site Location and Access	The quarry is located on Haerses Road, off Wisemans Ferry Road, to the west of the intersection with Old Northern Road. The current vehicle access is via Haerses Road which will continue to be used for the proposed expansion on the project site
2.2.1 Road Hierarchy	The main road through the locality is **Old Northern Road**, which runs in a north south direction to the west of the subject site. It provides an important road link through the locality, providing a connection for a number of rural suburbs between Wisemans Ferry to the north and Baulkham Hills and the greater area of Sydney to the south. In the locality of the subject site it generally provides a single lane of travel in each direction with additional turn lanes at key locations to maintain capacity. It operates under the posted speed limit of 80 km/h in the vicinity of the site and the intersection with Wisemans Ferry Road. There are no footpaths

Item	Response
	along the road in the location of the site with minimal sealed shoulders, reflective of the rural setting in this locality. **Wisemans Ferry Road** connects with **Old Northern Road** to the east of the site. Wisemans Ferry Road provides a sealed width in the order of 6m operating effectively under a speed limit of 80 km/h with a varying width sealed shoulder with a minimal verge bounded by small trees and shrubs. The road provides a route through to Richmond and the north-west sector of Sydney.
2.2.2 Roadworks	No road works are occurring within the general locality of the subject site. Given the reasonably low traffic flows in this area it can be seen that other than road maintenance there is no requirement for any major road upgrades in this location.
2.2.3 Traffic Management Works	None currently noted.
2.2.4 Pedestrian and Cycling Facilities	No pedestrian or cyclists facilities provided. Cyclists are able to use the road as required and there is generally very limited demand for pedestrian movements in this rural location due to the lack of local shops, schools etc.
2.2.5 Public Transport	There are no bus stops in the locality. It is noted that there are a number of school bus runs in this location and that buses pick up and drop off at informal locations along Old Northern Road adjacent to side roads and / or residents as required.
2.3 Traffic Flows	
2.3.1 Daily Traffic Flows	Daily traffic flows in the vicinity of the site are reasonably low, reflective of the rural location. As part of the project work, Seca Solution completed a traffic survey on Old Northern Road to the north of Maroota during the AM and PM peak periods during a typical working day (23rd November 2015). These counts shows that during the AM peak the 2-way flow was 146 vehicles per hour and 144vph in the PM peak. Based on the peak hour flow typically representing 10% of the daily flows, the daily traffic flows on this section of Old Northern Road could be in the order of 1,500 vehicles per day. Traffic surveys were also completed by Seca Solution on 4th December 2014 at the intersection of Old Northern Road and Wisemans Ferry Road, between 2.30PM and 5.00PM to determine the current traffic flows during the peak period associated with the Maroota Public School to the north of this location. These flows show that the two-way traffic flow on Old Northern Road to the north of Wisemans Ferry Road was 216 vehicles, indicating that daily traffic movements could be in the order of 2,100 vehicles per day, slightly higher than the surveys further north on Old Northern Road near Laughtondale Gully Road. Traffic flows on Wisemans Ferry Road, in the location of the site, were in the order of 176 vehicles during the afternoon peak period. This would indicate daily flows in the order of 1,800 per day.

Item	Response
2.3.2 Daily Traffic Flow Distribution	The peak hour traffic flows along Old Northern Road show a slight bias in traffic movements southbound in the AM peak, reflective of education and work opportunities to the south of the locality. In the PM peak the flows are reasonably evenly balanced. Daily traffic flows are expected to be equally balanced between northbound and southbound.
2.3.3 Vehicle Speeds	No speed surveys were completed as part of the study work. However, it is considered that the majority of drivers drive at the posted speed limit, due to the road alignment in the general locality of the site along Wisemans Ferry Road.
2.3.4 Existing Site Flows	The site is currently used for sand extraction with the current consent allowing for a maximum of 28 truck movements per day onto Hearses Road, with a limit of 10 trucks between 6-7 AM.
2.3.5 Heavy Vehicle Flows	There are a number of heavy vehicle movements in the locality, associated with the various quarries in the area as well as rural use demands. The vast majority of the heavy vehicle demands associated with the quarries are to the south of the locality, to the Greater Sydney area with very few heavy vehicles continuing north to Wisemans Ferry and beyond. A number of trucks were observed during the survey periods, associated with quarry activities and typical are truck and dog combinations.
2.3.6 Current Road Network Operation	The road network in the vicinity of the subject site currently operates very well with limited delays and congestion.
2.4 Traffic Safety and Accident History	The local road network in the general vicinity of the subject site is well laid out and caters safely for the overall traffic flows in the general vicinity of the subject site. Crash Data provided by the RMS for the past five years show that there have been no accidents recorded at the intersection of Haerses Road and Wisemans Ferry Road, Maroota. For the same period there has been only two crashes recorded at the intersection of Wisemans Ferry Road and Old Northern Road. One in 2010 and one in 2011. Neither involved a heavy vehicle. Overall it is considered that road safety in the locality of the subject site is good and that the limited number of heavy vehicles in the locality do not create any significant safety concerns.
2.5 Parking Supply and Demand	
2.5.1 On-street Parking Provision	There are no designated parking areas within the general locality of the site with parking demands catered for within the individual lots. Parking is permitted along the side of the roads if required on the verges, although observations on site show that there is little demand for road side parking in this area.
2.5.3 Parking Demand and Utilisation	There has been no demand for parking noted within the vicinity of the site.
2.5.4 Set down or pick up areas	There are no designated set down areas in the immediate locality of the subject site.
2.6 Public Transport	
2.6.1 Rail Station Locations	The location is not served by trains.

Item	Response
2.6.2 Bus Stops and Associated Facilities	There are no regular bus services to this location. There are a number of school bus runs that operate along Old Northern Road providing a service primarily for school students.
2.6.3 Pedestrians	There are no pedestrian footpaths within the vicinity reflecting the limited demand and rural setting.
2.7 Other Proposed Developments	No other significant developments noted in the immediate locality of the subject site. A new quarry has been approved on Laughtondale Gully Road to the north of the subject site.
Proposed Development	
3.1 The Development	Dixon Sand (Penrith) Pty Ltd (Dixon Sand) is seeking a modification to the existing development consent to expand the extraction area of the Hearses Road Quarry. The proposed modification does not seek to alter the overall number of truck movements in and out of the project site, but rather seeks to alter the potential truck movement patterns in and out of the project site. The proposed modification involves the following: - Maximum of 250,000 tonnes per annum exiting the site (NO change to current consent) - Maximum of 250,000 tonnes per annum direct to market (increase from current consent of 60,000 tonnes per annum) - Maximum of 190,000 tonnes per annum exit site to Old Northern Road site (NO change to current movements through township of Maroota) - Up to 100,000 tonnes per annum of VENM / ENM to / from site for processing. The 100,000 tonnes of VENM / ENM will be transported to the site in trucks that are currently entering the site empty to pick up a load for removal of product to either the associated Old Northern Road Quarry or to market. The consent does not seek to alter the overall number of truck movements in and out of the site (28 per day), but rather seeks to alter the potential truck movement patterns which currently restrict trucks to a maximum of 7 trucks movements to the south-west per day and increase this to a maximum of 28 per day. If the 28 truck movements per day turn left out of the site, there will be no trucks turning right out of the site, which is currently restricted to 28 per day maximum.
3.1.1 Nature of Development	Sand extraction quarry
3.1.2 Access and Circulation Requirements	Access will be provided via the existing access along Hearses Road which then connects with Wisemans Ferry Road. The layout of the site and the operations allows for all vehicles to enter and exit the site in a forward direction. There is no change to the current access arrangements for the project.
3.2 Access	The access to the site will be via the existing access on Hearses Road. Hearses Road connects with Wisemans Ferry Road via a simple Give Way control, with Hearses Road being located on the

Item	Response
	outside of the slight curve in this location which allows for good visibility for vehicles entering and exiting Hearses Road. This access currently caters for all turning movements associated with the current operations on the site, which allow for trucks and light vehicles to enter and exit Hearses Road from the east and west on Wisemans Ferry Road.
3.2.1 Driveway Location	The driveway access to the site is located at the end of Hearses Road and effectively operates as the terminus of Hearses Road.
3.2.2 Sight Distances	The intersection of Hearses Road and Wisemans Ferry Road is a simple T intersection, with Wisemans Ferry Road being the priority road. There is a short length of sheltered right turn lane that allows for the vehicles turning right off Wisemans Ferry Road into Hearses Road. The sight distances at this location are restricted, due to curvature of the roads and the road side vegetation. For the posted speed limit of 80 km/h, the required safe intersection sight distance is 160 metres, whilst the stopping sight distance requirement is 100 metres. The sight distance available in both directions is approximately 140 metres, which equates to a design speed of 70 km/h. The alignment of the road in the locality of the intersection with Hearses Road does not encourage speeding with vehicles typically travelling at lower than the posted speed limit. The sight distance available exceeds the requirements under Approach Sight Distance requirement of 100 metres under Austroads requirements. Approach Sight Distance allows an approaching driver to appreciate the intersection geometry and pavement markings in order to negotiate the intersection or stop (if necessary). Whilst the safe intersection sight distance is short be 20m this existing access appears to operate in a safe manner with vehicles able to observe the intersection and adjust speeds accordingly. Based upon observations on site and a review of the current operations on site, it is considered that the intersection of Hearses Road and Wisemans Ferry Road can continue to operate to an acceptable standard for the proposed modification of the quarry. It is noted that the proposed modification will not increase the current number of truck movements using this intersection associated with the quarry.
3.2.3 Service Vehicle Access	The site will require limited servicing and the service vehicles will typically be required for maintenance of construction vehicles on site, tyre changes, etc. These vehicles will typically be a small rigid truck or smaller. The number of service vehicles is not expected to alter with the proposed modification.
3.2.4 Queuing at entrance to site	No vehicle queues expected at site entry / exit point due to the low overall flows from the site as well as low flows on Wisemans Ferry Road. Observations on site during a typical morning and afternoon peak period showed that the current intersection of Hearses Road and

Item	Response
	Wisemans Ferry Road operates very well, with no delays or congestion noted. The vast majority of turn movements in and out of Hearses Road occurred with no delays other than the geometric delay created by the intersection, with the through movement on Wisemans Ferry Road being low and accordingly leaving large gaps in the traffic movements. This pattern also occurs at the intersection of Wisemans Ferry Road and Old Northern Road, with no delays for the vast majority of drivers other than those associated with negotiating the intersection.
3.2.5 Comparison with existing site access	Existing site access is via Hearses Road and there will be no change to this access required or proposed.
3.2.6 Access to Public Transport	There is very limited access to public transport in this area and it is considered that employees associated with the project will not rely on public transport to access the site.
3.3 Circulation	
3.3.1 Pattern of circulation	All vehicles can enter and exit the site in a forward direction and circulate around the site as required.
3.3.2 Road width	The existing internal roads allow for two-way traffic movements as required and given the very low traffic movements associated the development the existing internal road does not create any issues.
3.3.3 Internal Bus Movements	No internal bus movement will be required for this modifcation.
3.3.4 Service Area Layout	No specific service area layout required. A maintenance shed is provided on site to allow for vehicle maintenance as required.
3.4 Parking	
3.4.1 Proposed Supply	A gravel car parking providing 12 spaces (8 staff and 4 visitor) will be located adjacent to Haerses Road at the weighbridge. There will be no trucks parked on the site overnight.
3.4.2 Authority Parking	No specific parking rate provided for the development land use under The Hills Development Control Plan. Similarly, the RMS Guide to Traffic Generating Developments makes no recommendations for parking for extractive industries. Thus the parking is to be provided based upon the actual demand of the end user.
3.4.3 Parking Layout	No formal parking bays to be provided. Parking will occur adjacent to the weighbridge and/or maintenance shed.
3.4.4 Parking Demand	Normal parking demands can be accommodated within the site.
3.4.5 Service Vehicle Parking	Service vehicles can be accommodated within the site as required.
3.4.6 Pedestrian and Bicycle Facilities	It is considered that there will be no demand for pedestrian or cycle access given the remote location of the site and as such, no formal facilities will be provided.
Traffic Assessment	
4.1 Traffic Generation	There are no standard traffic generation rates provided by the RTA Guide to Traffic Generating Development for this type of development and as such the generation should be based upon the future operational characteristics of the site.

Item	Response
	The modification will allow for the continual extraction of up to 250,000 tonnes of material per annum from the site. This means that the current limit of truck movements in and out of the site will remain at the current levels i.e. 28 per day. Currently a maximum of 190,000 tonnes is extracted from the site and proceeds north on Old Northern Road to the other facilities operated by Dixon Sands. This will not change under the proposed modification. Currently, a maximum of 60,000 tonnes per annum (out of the total of 250,000 tonnes per annum) is extracted from the site and dispatched directly to the market. The modification seeks to increase this to a maximum of 250,000 tonnes per annum direct to market. If the full quantity of 250,000 tonnes per annum is extracted and delivered direct to market, then there will be no material moved to the site on Old Northern Road to the north of Maroota. The proposal will also allow for the import of VENM and ENM material, up to 100,000 tonnes per annum. This will utilise empty trucks travelling to the site, which will then carry the outbound material from the site. Currently these inbound trucks do not carry a load. This ensures that the modification will continue to operate under the current limit of 28 trucks per day (inbound and outbound) The hours of operation for the quarry will be Monday to Saturday 7am to 6pm. The modification will result in a maximum of 28 truck movements per day (no change) and a limit of 10 trucks per hour between 6-7 AM.
4.1.1 Other Developments	No other significant developments are noted within the locality of the site. A quarry has been approved on Laughtondale Gully Road to the north of the subject site. This will generate traffic movements along Old Northern Road, once it becomes fully operational.
4.1.3 Daily and Seasonal Factors	Operational traffic associated with the quarry is in response to market demands. There will be a significant daily variation in traffic movements as a consequence of this. At times there may be no demand and as such there will be no activity in and out of the quarry.
4.1.4 Pedestrian Movements	No pedestrian movements are expected to and from the site. All internal pedestrian movements will be covered by WH&S guidelines.
4.2 Traffic Distribution and Assignments	The traffic movements will allow for access in both directions along Wisemans Ferry Road dependent upon the market demands. Current traffic movements are limited to a maximum of 7 trucks to the west of Hearses Road with the balance, up to 28 trucks per day, to the east on Hearses Road. The modification allows for the maximum of 28 trucks per day to remain, but allowance for up to 28 trucks to use either Wisemans Ferry Road to the east or west of Hearses Road.

Item	Response
4.2.1 Origin / destinations assignment	100% of trucks will enter and exit via Hearses Road only. Up to 28 trucks per day will travel along Wisemans Ferry Road with no restriction on how many of these travel to the west or to the east. Those travelling east will then access the broader network along Old Northern Road (north or south dependent upon if outbound material to market or transport to other Dixon Sands site to north of Maroota).
4.3 Impact on Road Safety	It is considered that the project will have a minimal impact upon road safety in the general locality of the subject site. The modification does not allow for any increase in the number of truck movements, just a re-allocation of truck movements onto the road network and allowing empty trucks to carry inbound material. The road network in the locality of the subject site operates well with minimal delays. The rural nature of the locality does not encourage high traffic speeds and the road alignment of Wisemans Ferry Road and Old Northern Road both allow for safe traffic movements. There are already a number of quarry related truck movements in the area which generate heavy vehicle movements and these overall movements will not increase due to the modification. The modification will not increase the number of truck movements passing through the township of Maroota and past Maroota Pubic School in this location and therefore will not have an impact on safety at this location.
4.4 Impact of Generated Traffic	
4.4.1 Impact on Daily Traffic Flows	It is considered that the traffic movements generated by the modification will have a minimal impact on the daily traffic movements in the immediate locality of the subject site. The development will not generate any additional traffic movements but allows for a different distribution of traffic which is only low. The development will continue to generate 28 truck movements per day (inbound and outbound). Current daily flows on Old Northern Road, based upon the peak hour surveys completed by Seca Solution, are in the order of 1,500 vehicles per day well within acceptable limits for the local roads in this location. The trucks are currently using this road and as such there is no impact. For the alternative access route, with the market demand requiring all 28 trucks to head to market via Wiseman Ferry Road to the south-west of the site, the current daily traffic flows are in the order of 2,100 in the vicinity of the site. It is considered that the additional 28 truck movements per day in both directions would have a negligible impact upon the operation of this road in this location. It is noted that the current consent permits up to 7 trucks per day via this route and so the proposal is to increase this by 21 trucks per day per direction maximum.

Item	Response
4.4.2 Peak Hour Impacts on Intersections	The key intersections identified as being potentially affected by the modification is the T intersection of Hearses Road with Wisemans Ferry Road and Wisemans Ferry Road with Old Northern Road. Observations on site show that both of these intersections operate very well with no delays for the majority of traffic movements. Traffic turning into or out of the side road typically did not need to stop and the only delay was that associated with manoeuvring through the intersection. A Sidra intersection analysis has been completed at the intersection of Old Northern Road and Wisemans Ferry Road and the analysis confirms that the intersection operates very well with negligible delays and congestion. Levels of service for all movements are A and the delays are less than 7 seconds for all movements. It is considered that the intersection of Hearses Road and Wisemans Ferry Road would operate to a similar level of service and delays. With no increase to the truck numbers at this location the intersection will continue to operate at this level of service. Traffic flows are lower than at the intersection of Old Northern Road and Wisemans Ferry Road and observations on site show that this intersection currently operates with negligible delays for all traffic movements.
4.4.3 Impact of Construction Traffic	All construction work will be contained within the site so minimal impact upon external road network. The majority of the equipment is located on the site and will be able to continue to be used and as such there will be little if any additional construction traffic movements.
4.4.4 Other Developments	No other significant developments occurring in the immediate locality of the subject site.
4.5 Public Transport	
4.5.1 Options for improving services	No requirements to improve services.
4.5.2 Pedestrian Access to Bus Stops	None required
4.6 Recommended Works	
4.6.1 Improvements to Access and Circulation	No improvements for access to the internal road network is proposed. The internal roads allow for safe and efficient movement of vehicles and will not allow for general public access.
4.6.2 Improvements to External Road Network	None required as the development will not increase the traffic demands associated with the site.
4.6.3 Improvements to Pedestrian Facilities	No upgrades required.
4.6.4 Effect of Recommended Works on Adjacent Developments	No impact as no external works recommended.
4.6.5 Effect of Recommended Works on Public Transport Services	Nil
4.6.6 Provision of LATM Measures	None required

Item	Response
4.6.7 Funding	No external road upgrades required.

Photo 1 – View north along Old Northern Road showing typical alignment and approach to Wisemans Ferry Road

Photo 2 – View to left for drivers exiting Wisemans Ferry Road onto Old Northern Road

Photo 3 – View to right for drivers exiting Wisemans Ferry Road onto Old Northern Road

Conclusion

From the site work completed and the review of the proposed modification, it is considered that the proposed quarry expansion will have a minimal impact upon the overall road network within the general vicinity of the site.

The site access can continue to operate in a safe manner and allows for vehicles to enter and exit the site in a safe manner, via the intersection of Hearses Road and Wisemans Ferry Road. This intersection currently allows for safe turning movements and provides adequate sight lines to maintain road safety.

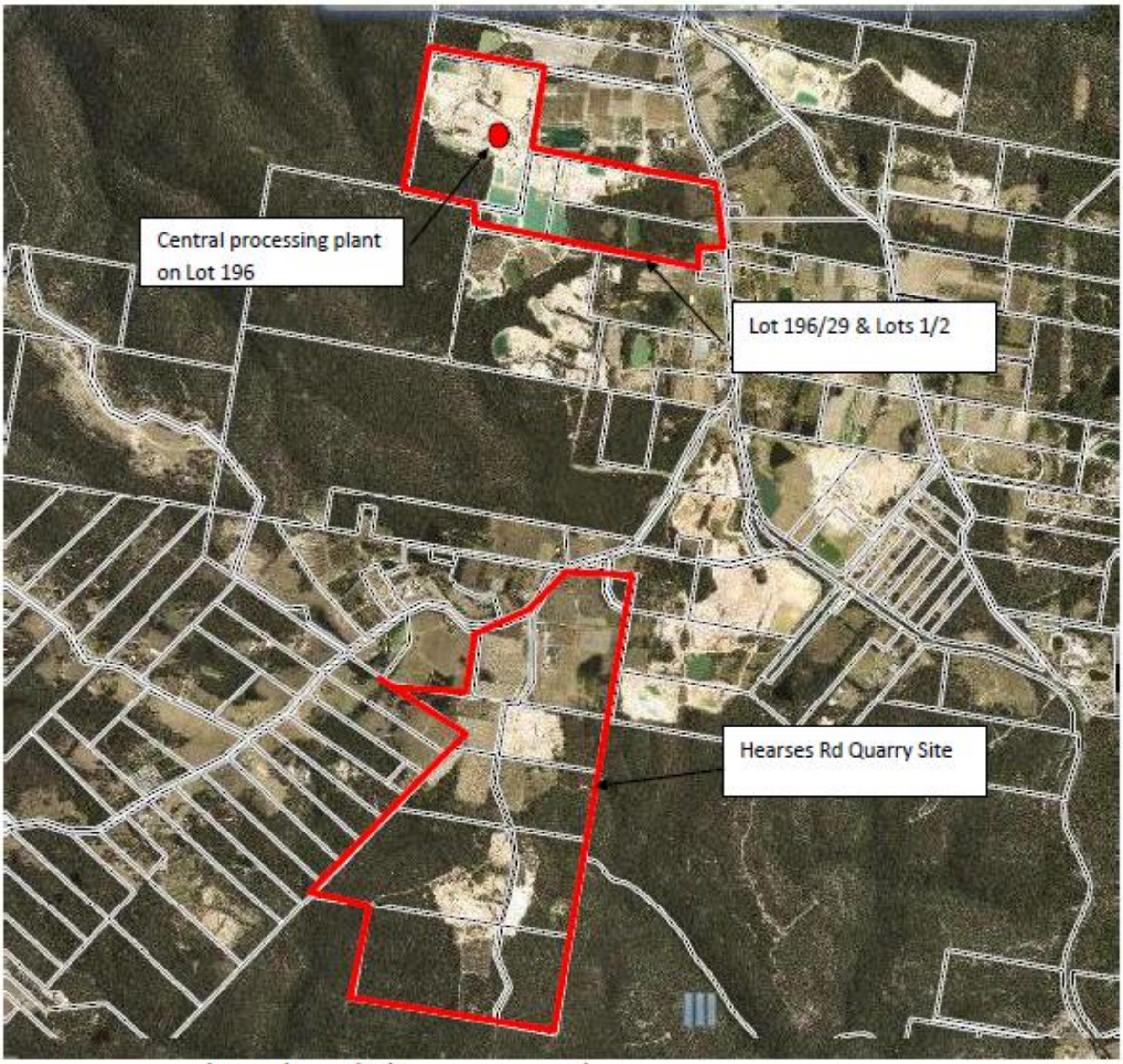
The modification will maintain the daily truck movements associated with the quarry at 28 per day via Hearses Road however allows for a different distribution direct to the market, with up to 28 trucks per day travelling east or west along Wisemans Ferry Road, dependent upon the market demands. The current consent permits up to 28 truck movements per day on Old Northern Road heading south so there is no change created by the modification. If the market demand is for 28 truckloads per day to head south-west then this will potentially increase the truck movements on Wisemans Ferry Road to the south-west of the site from the current consent of 7 per day each way to 28 per day each way. This will have a minimal impact upon the operation of Wisemans Ferry Road. There will be no increase to the number of trucks heading north via Maroota carrying product between the project site and the other Dixon Sands site north of Maroota and the delivery of product direct to market has the potential to actually reduce these movements. The import of VENM or ENM product, utilising empty trucks inbound to the quarry, will not impact on the number of movements but rather utilise existing trucks on the road network.

It is therefore concluded that the development should be approved on traffic and access grounds.

Sean Morgan

Director

Attachment A - Site Plan Location and Plan



Attachment B - Accident Data

Summary Crash Report

Transport for NSW — Centre for Road Safety

# Crash Type		
Car Crash	1	50.0%
Light Truck Crash	0	0.0%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	0	0.0%
'Heavy Truck Crash	(0)	(0.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(0)	(0.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	50.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	1	50.0%
Non intersection	1	50.0%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	1	50.0%
Multi Vehicle	1	50.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	0	0.0%
Other Classified Road	2	100.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	0	0.0%
Fatigue	0	0.0%

Weather		
Fine	1	50.0%
Rain	1	50.0%
Overcast	0	0.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	1	50.0%
Dry	1	50.0%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	2	**********
Dusk	0	0.0%
Darkness	0	0.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	1	50.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	1	50.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	0	0.0%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit					
40 km/h or less	0	0.0%	80 km/h zone	1	50.0%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	0	0.0%	100 km/h zone	0	0.0%
70 km/h zone	1	50.0%	110 km/h zone	0	0.0%

CRASHES	2	
Fatal	0	0.0%
Serious inj.	0	0.0%
Moderate inj.	1	50.0%
Minor/Other inj.	1	50.0%
Uncategorised inj.	0	0.0%
Non-casualty	0	0.0%

Self Reported Crash	0	0%

CASUALTIES	2	
Killed	0	0.0%
Seriously inj.	0	0.0%
Moderately inj.	1	50.0%
Minor/Other inj.	1	50.0%
Uncategorised inj.	0	0.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
1	2011	1
1	2010	1

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	0	0.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	1	50.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	1	50.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	0	0.0%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

McLean Periods			% Week
A	0	0.0%	17.9%
B	0	0.0%	7.1%
C	0	0.0%	17.9%
D	2	100.0%	3.5%
E	0	0.0%	3.6%
F	0	0.0%	10.7%
G	0	0.0%	7.1%
H	0	0.0%	7.1%
I	0	0.0%	12.5%
J	0	0.0%	10.7%

Street Lighting Off/Nil			% of Dark	
0	of	0	in Dark	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less	0	0.0%	~ School Travel Time Involvement	0	0.0%

Day of the Week														
Monday	0	0.0%	Wednesday	0	0.0%	Friday	0	0.0%	Sunday	0	0.0%	WEEKEND	2	**********
Tuesday	0	0.0%	Thursday	0	0.0%	Saturday	2	**********	WEEKDAY	0	0.0%			

#Holiday Periods																	
New Year	0	0.0%	Easter	0	0.0%	Queen's BD	0	0.0%	Christmas	0	0.0%	Easter SH	1	50.0%	Sept./Oct. SH	0	0.0%
Aust. Day	0	0.0%	Anzac Day	0	0.0%	Labour Day	0	0.0%	January SH	0	0.0%	June/July SH	0	0.0%	December SH	0	0.0%

Crashid dataset 6820 - Reported crashes within 20m of intersection - Wisemans Ferry Rd & Old Northern Rd - 1 July 2010 to 30 June 2015

***Note:** Crash self reporting, including self reported injuries began Oct 2014. Trends from 2014 are expected to vary from previous yrs. More unknowns are expected in self reported data. Reporting yrs 1996-2004 and 2014 onwards contain uncategorised inj crashes.*

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Sydney **User ID:** nafiza Page 1 of 1 Generated: 09/05/2016 08:06

APPENDIX 5

Air Quality Assessment

Pacific Environment Limited

Consulting • Technologies • Monitoring • Toxicology

Report

DIXON SAND HAERSES ROAD QUARRY MODIFICATION – AIR QUALITY ASSESSMENT

DIXON SAND QUARRY C/O UMWELT

Job ID. 21153B

13 September 2016

PROJECT NAME:	Dixon Sand Haerses Road Quarry Modification – Air Quality Assessment
JOB ID:	21153B
DOCUMENT CONTROL NUMBER	AQU-NW-001-21153
PREPARED FOR:	Dixon Sand Quarry c/o Umwelt
APPROVED FOR RELEASE BY:	Judith Cox
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EXECUTIVE SUMMARY

Pacific Environment has prepared this air quality assessment on behalf of Dixon Sand Pty Ltd (the Proponent). It assesses the air quality impacts associated with the proposed additional extraction area and other changes to the current operations at the Haerses Road site (the Modification).

The assessment was prepared in general accordance with the NSW EPA "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (*Approved Methods*) (**NSW DEC, 2005**).

The surrounding land use is primarily rural, although there is significant sand extraction activity in the area, both by Dixon Sand and other companies.

AERMOD was chosen as the most suitable model due to the source types, location of nearest receivers and nature of local topography. AERMOD is the US-EPA's recommended steady-state plume dispersion model for regulatory purposes and is now commonly applied to assessments of this nature in NSW.

The operational stage has been modelled for average annual production. A worst case 24-hour operational scenario has also been modelled accounting for maximum daily throughput. Two scenarios were assessed to account for dry processing activities that could occur in different locations on site.

The results of the modelling indicate that the predicted incremental PM_{10}, $PM_{2.5}$, TSP and dust deposition at the closest sensitive receivers all comply with the impact assessment criteria.

A cumulative assessment, incorporating existing background levels, indicates that the Modification may result in some additional exceedances of relevant impact assessment criteria at the closest sensitive receptors, if the worst day operations happened to coincide with already elevated background concentrations. However this outcome is considered unlikely to occur and the current requirements to modify/cease operations if rolling 24-hour averages exceed 42 $\mu g/m^3$ will minimise the potential for this to occur even further.

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1 INTRODUCTION

Dixon Sand (Penrith) Pty Limited (Dixon Sand) operates the Haerses Road Quarry located on Haerses Road at Maroota, NSW. Dixon Sand extracts Tertiary Maroota Sand from the Haerses Road Quarry from Lot 170 DP 664767, Lots A and B DP 407341, and Lots 176 and 177 DP 752039 in accordance with development consent DA 165-7-2005.

Pacific Environment has prepared this air quality assessment for Dixon Sand (the Proponent) to assess the air quality impacts associated with the proposed additional extraction area and other changes to the existing sand quarrying activities at the Haerses Road Quarry. The additional extraction area relates to a friable sandstone resource to the west of the existing tertiary sand resource (the Modification).

The assessment has been prepared in general accordance with the NSW EPA "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW", hereafter referred to as the *Approved Methods* (**NSW DEC, 2005**).

2 PROJECT DESCRIPTION

The Proponent has been operating the Haerses Road Quarry since consent was granted in 2006. The resource contains a Tertiary deposit of eluvial sediments that are suited for use as concrete and specialty sands.

DA 165-7-2006-5 currently allows a total extraction of 7 million tonnes from the site over 25 years at a rate of 250,000 tonnes per annum (tpa). The consent allows for hauling of 190,000 tpa of screened sand to the processing facility at Dixon Sand's Old Northern Road Quarry located approximately two kilometers to the north, and hauling of 60,000 tpa of screened sand direct to local and regional markets.

The proposed modification to DA 165-7-2006-5, being sought for the Haerses Road Quarry involves increasing the extraction area as well as including a provision for mobile plant and equipment to be utilised on the site to avoid double handling and double processing of the product. The proposed modifications are:

- Increasing the extraction area by approximately 19 hectares to allow extension into the friable sandstone resource within Lots 177 DP 752039 and 216 DP 752039. The friable sandstone would be extracted using similar methods and equipment as currently used at the site, being a dozer, excavator, trucks and a loader. The existing dozer would be used to rip the friable sandstone on site which wasn't required for tertiary sand deposit in the original consent. The existing dry screening plant would utilise mobile crushers (one jaw crusher and one rotary crusher) to break sandstone clumps prior to screening;
- Utilise existing traffic movements between Old Northern Road and Hearses Road Quarries to allow for blending of speciality sands, including importation of up to 100,000 tpa of clean recycled sands (Virgin Excavated Natural Material (VENM) and Excavated Natural Material (ENM)) from approved sites. No new traffic movements would be generated by the proposal and there would be negligible change to traffic generation between quarries as a result of the proposed modification;
- Use of mobile washing and processing plant on site, utilising water from existing water licence provisions;
- Installation of detention basins; and
- Establishment of site office, workshop and weighbridge.

An Air Quality Assessment has been prepared as part of the modification application for the proposed expansion of the quarry, in accordance with Section 75W of the *Environmental Planning and Assessment Act 1979*.

3 LOCAL SETTING

The land use in the area surrounding the proposed development is primarily rural, although there is significant sand extraction activity in the area, both by Dixon Sand and other companies.

The closest discrete receptor locations are presented in **Table 3.1**. These residential receivers (some of which are owned by Dixon Sand and PF Formation, as stated) represent assessment locations in close proximity to the Modification (see **Figure 3.1**).

Table 3.1: Receptor Locations

Receptor ID	Type	Easting (m)	Northing (m)	Height ASL (m)
R1	Residential	312924	6295200	195
R2	Residential	312780	6295033	193
R3	Residential	312454	6294919	179
R4	Residential	312177	6294850	176
R5	Residential	311939	6294631	162
R6	Residential	311871	6294275	156
R7	Residential	311600	6294343	161
R8	Residential	311702	6294162	153
R9	Residential	311543	6294146	147
R10	Residential	311283	6294161	153
R11	Residential	311179	6294076	155
R12	Residential	313049	6295163	196
R13	Residential	313018	6295228	198
R14	Residential	312353	6295030	184
R15	Residential	312207	6294990	183
R16	Residential	312103	6295021	178
R17	Residential	310707	6293300	145
R18	Residential	311239	6292850	134
R19	Residential	311627	6292424	132
R20	Residential	311873	6291990	149
D1	Owned by Dixon Sand	313103	6295173	196
PF1	Owned by PF Formation	313362	6295255	205
PF2	Owned by PF Formation	313242	6295125	198
PF3	Owned by PF Formation	313228	6294961	189

Dixon Sand's central processing plant at the Old Northern Road site, the Haerses Road site and sensitive receptors are shown in **Figure 3.1**.

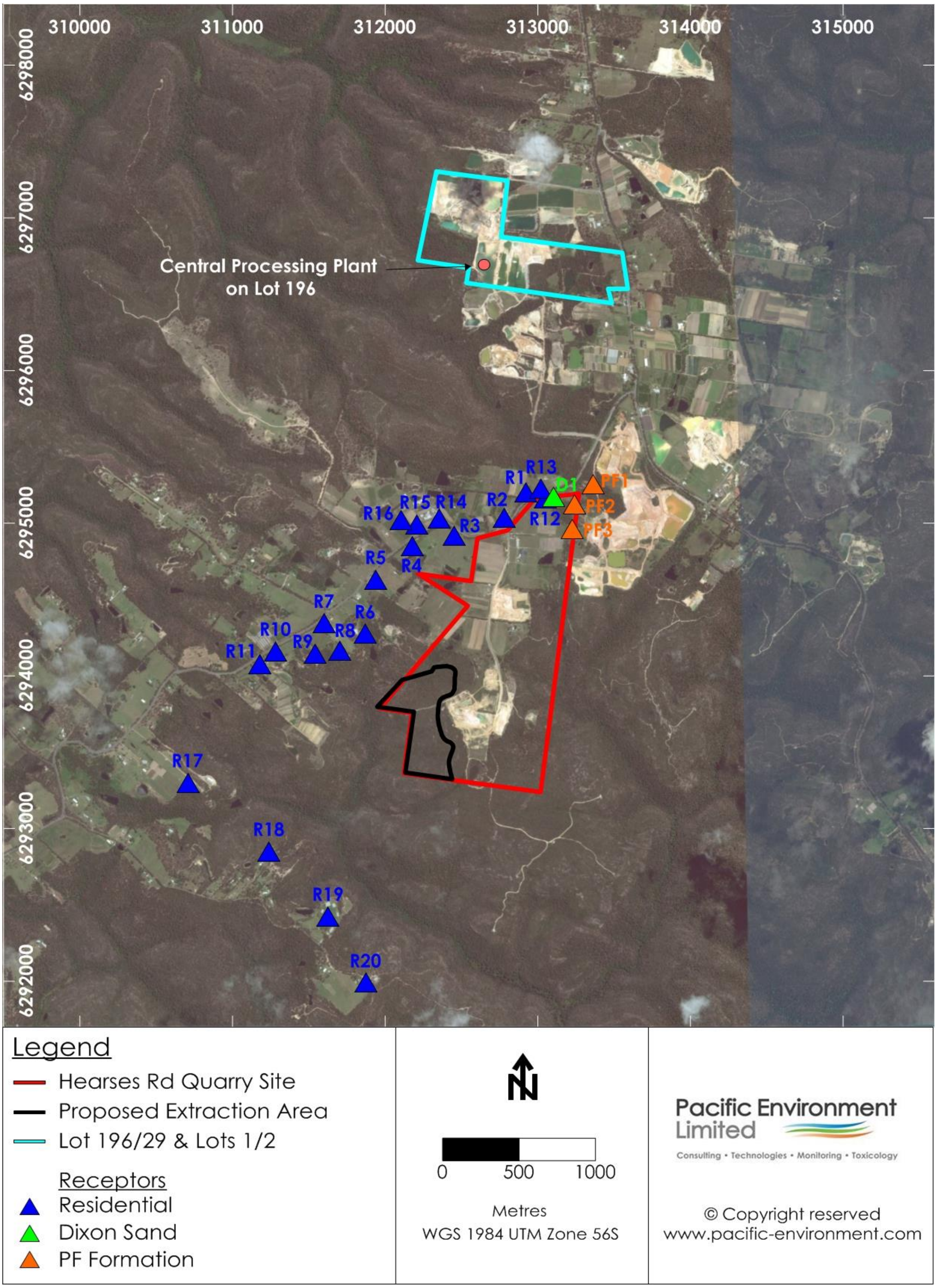


Figure 3.1: Location of the Haerses Road Quarry and Sensitive Receptors

4 AIR QUALITY CRITERIA

The potential emissions to air from the Modification are summarised as follows:

- Modification activities described in **Section 2** have the potential to generate fugitive dust emissions, particularly from sand extraction, hauling and site rehabilitation.
- Combustion of diesel in quarrying equipment will result in emissions of fine fractions of particulate matter (PM_{10} and $PM_{2.5}$), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2) and organic compounds. This assessment focuses on the key pollutants of fine PM.

It is noted that emissions of PM from diesel exhaust are considered to be accounted for in the emission factors for fugitive PM for relevant sources (i.e. dozers).

4.1 Impact Assessment Criteria

The Approved Methods specifies air quality assessment criteria relevant for assessing impacts from air pollution (**NSW DEC, 2005**). These criteria are health-based (i.e. they are set at levels to protect against health effects) and for PM_{10} are consistent with the now superseded National Environment Protection Measure for Ambient Air Quality (referred to as the Ambient Air-NEPM) (**NEPC, 1998a**). However, the Approved Methods include other measures of air quality, namely dust deposition and TSP which are not stated in the Ambient Air-NEPM.

In January 2016, the NEPC released an amended Ambient Air-NEPM (**NEPC, 2016**) to take into account the latest scientific evidence about the health impacts of particles. The amendment changed the 'advisory reporting standards' status for annual average and 24-hour average $PM_{2.5}$ (particulate matter with an equivalent aerodynamic diameter of 2.5 µm or less) to 'standards', but in absence of any other relevant standard/goal, the 2016 NEPM for $PM_{2.5}$ standards have been used in this report for comparison against dispersion modelling results.

Table 4.1 presents the air quality goals for pollutants that are relevant to this study. It is important to note that the criteria are applied to the cumulative impacts due to the Modification and other sources.

Table 4.1: NSW EPA Air Quality Standards/Goals for Particulate Matter Concentrations

Pollutant	Standard	Averaging Period	Source
TSP	90 µg/m³	Annual	NSW DEC (2005) (assessment criteria)
PM_{10}	50 µg/m³	24-Hour	NSW DEC (2005) (assessment criteria)
	30 µg/m³	Annual	NSW DEC (2005) (assessment criteria)
$PM_{2.5}$	25 µg/m³	24-Hour	NEPC (2016)
	8 µg/m³	Annual	NEPC (2016)
Nitrogen Dioxide	246 µg/m³	1-Hour	NSW DEC (2005) (assessment criteria)
	62 µg/m³	Annual	NSW DEC (2005) (assessment criteria)

Notes: µg/m³ – micrograms per cubic metre.

In addition to health impacts, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including vegetation. Larger particles do not tend to remain suspended in the atmosphere for long periods of time and will fall out relatively close to source. Dust deposition can soil materials and generally degrade aesthetic elements of the environment, and are assessed for nuisance or amenity impacts.

Table 4.2 shows the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective. These criteria for dust deposition levels are set to protect against nuisance impacts (**NSW DEC, 2005**).

Table 4.2: EPA Criteria for Dust (Insoluble Solids) Fallout

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

Notes: g/m^2/month – grams per square metre per month.

4.2 Crystalline Silica

Whilst dust generated from the Modification may contain silica dust, and long term inhalation of silica dust may lead to the formation of scar tissue in the lungs, which can result in silicosis, a serious lung disease, silicosis is a work place issue associated with long-term exposure to high levels of respirable crystalline silica (RCS).

The World Health Organization's Concise International Chemical Assessment Document on Crystalline Silica, Quartz (**CICAD, 2000**) states that "*there are no known adverse health effects associated with the non-occupational exposure to quartz*". In addition, an Australian Government Senate Committee (**2005**) report identified that there are no reports in the international literature of individuals developing silicosis as a result of exposure to non-occupational levels (i.e. levels outside the work place) of silica dust, and an expert appearing before the committee confirmed the potential for such an occurrence as being very remote.

A literature review on the potential impacts to health from exposure to crustal material in Port Hedland, WA, states "exposure to airborne quartz carries the risk of silicosis, but only with prolonged exposure to concentrations greater than 200 µg/m^3" (**Department of Health, 2007**). As detailed in **Section** 7 the maximum cumulative annual average PM_{10} concentrations (of which RCS would be a small fraction) at the most affected residence is predicted to be 14.7 µg/m^3 (of which 13 µg/m^3 is due to existing background levels), significantly below levels that may be of concern. For this reason, RCS has not been considered further in this assessment.

5 EXISTING ENVIRONMENT

5.1 Local Climatic Conditions

Table 5.1 presents the temperature, humidity and rainfall data for the Bureau of Meteorology site located at Peats Ridge (Site number 061351), approximately 28 km northeast of the site. Humidity data consist of monthly averages of 9 am and 3 pm readings. Also presented are monthly averages of maximum and minimum temperatures. Rainfall data consist of mean monthly rainfall and the average number of rain days per month.

The annual average maximum and minimum temperatures recorded at the Peats Ridge station are 21.8°C and 11.3 °C respectively. On average, January is the hottest month, with an average maximum temperature of 27.0°C. July is the coldest month, with average minimum temperature of 6.1°C. The annual average relative humidity reading collected at 9am from the Peats Ridge station is 75% and at 3pm the annual average is 62%. The months with the highest relative humidity on average are February and March with 9am averages of 82% and the month with the lowest relative humidity is September with a 3pm average of 54%.

Rainfall data collected at the Peats Ridge station shows that February is the wettest month, with an average rainfall of 154.3 mm over an average of 14.1 rain days. The average annual rainfall is 1248.6 mm with an average of 137 rain days per year.

Table 5.1: Climate Averages for the Peats Ridge Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
9am Mean Dry-bulb and Wet-bulb Temperatures (°C) and Relative Humidity (%)													
Dry-bulb	21.1	20.5	19.0	17.2	14.1	11.3	10.5	12.1	15.2	17.6	18.4	20.2	16.4
Humidity	78.0	82.0	82.0	78.0	79.0	78.0	75.0	69.0	65.0	65.0	72.0	74.0	75.0
3pm Mean Dry-bulb and Wet-bulb Temperatures (°C) and Relative Humidity (%)													
Dry-bulb	25.3	24.8	23.1	20.4	17.5	15.0	14.4	16.3	18.7	20.8	22.1	24.1	20.2
Humidity	64.0	66.0	66.0	66.0	67.0	66.0	60.0	55.0	54.0	58.0	61.0	63.0	62.0
Daily Maximum Temperature (°C)													
Mean	27.0	26.4	24.6	22.0	19.1	16.4	15.8	17.7	20.5	22.8	24.1	25.8	21.8
Daily Minimum Temperature (° C)													
Mean	16.3	16.4	14.6	12.0	9.5	7.2	6.1	6.6	8.7	10.9	13.0	14.8	11.3
Rainfall (mm)													
Mean	113.3	154.3	135.9	123.0	89.7	99.5	62.7	74.0	69.1	85.3	100.7	92.4	1248.6
Rain days (Number)													
Mean	13.8	14.1	14.1	11.3	11.4	10.5	9.7	8.4	8.3	10.6	12.4	12.7	137.3

*Source: **BOM (2016)** Climate averages for Station: 061351; Commenced: 1981 – Last Record 2015; Latitude: 33.31°S; Longitude: 151.24 °E*

5.2 Local Meteorology

5.2.1 Wind Speed and Direction

Air quality impacts are influenced by meteorological conditions, primarily in the form of gradient wind flow regimes, and by local conditions that are generally driven by topographical features and interactions with coastal influences, such as the sea breeze. Wind speed, wind direction, temperature and relative humidity all affect the potential dispersion and transport of plumes and are basic input retirements for dispersion modelling.

Wind speed and direction data have been collected locally at the Maroota Public School, approximately 3 km north of the Haerses Road site. The annual and seasonal 2015 wind roses for the weather station are presented in **Figure 5.1** (right side)**.** The wind speeds recorded at the site are very light with an average wind speed for the period of 1.2 m/s. The percentage of calms (wind speeds below 0.5 m/s) for the station are relatively high at 16.5%.

The predominant winds are from the north, east and southwest quadrants on an annual basis. Summer and spring winds are predominantly from the east and south-south-west while for the other seasons the winds are primarily from the north and west.

Given the lack of cloud data available from the closest BoM weather station at Richmond RAAF, data was produced using The Air Pollution Model (TAPM), through an integration of the onsite wind speed and direction available. This data, along with the other appropriate meteorological parameters were used in the modelling.

5.2.2 Suitability of Meteorology

The suitability of the meteorology for the project area has been completed through a comparison to previously recorded data from the weather station at the Maroota Public School and the BoM Richmond RAAF AWS.

Shown in **Appendix C** are windroses for the Maroota Public School (period April 2013 – March 2014 and April 2014 – March 2015). It is apparent that the seasonal wind directions vary between the windroses presented for the respective periods. Further, the measured wind speeds and hence percentage of calms varies greatly. It was detailed to Pacific Environment that the logger recording the data in the weather station had been changed during the years presented. However no additional information was provided on this matter and hence the meteorological data collected for these periods was not considered suitable for modelling.

The appropriateness of the 2015 data is highlighted through a comparison to the BoM Richmond RAAF AWS in **Figure 5.1**. It must be noted that this site is a significant distance from Richmond RAFF (26 km) and is subject to a flatter terrain, however as shown the wind directions and percentage of calms is highly comparable.

In summary, based upon the data avaliable and discrepancies outlined from previous years, the wind data collected at Maroota Public School for 2015 were found to be generally representative of the larger data set in terms of average wind speed, percentage of calms and directional patterns. Therefore it was selected to represent the meteorology at the project area in the air quality assessment.

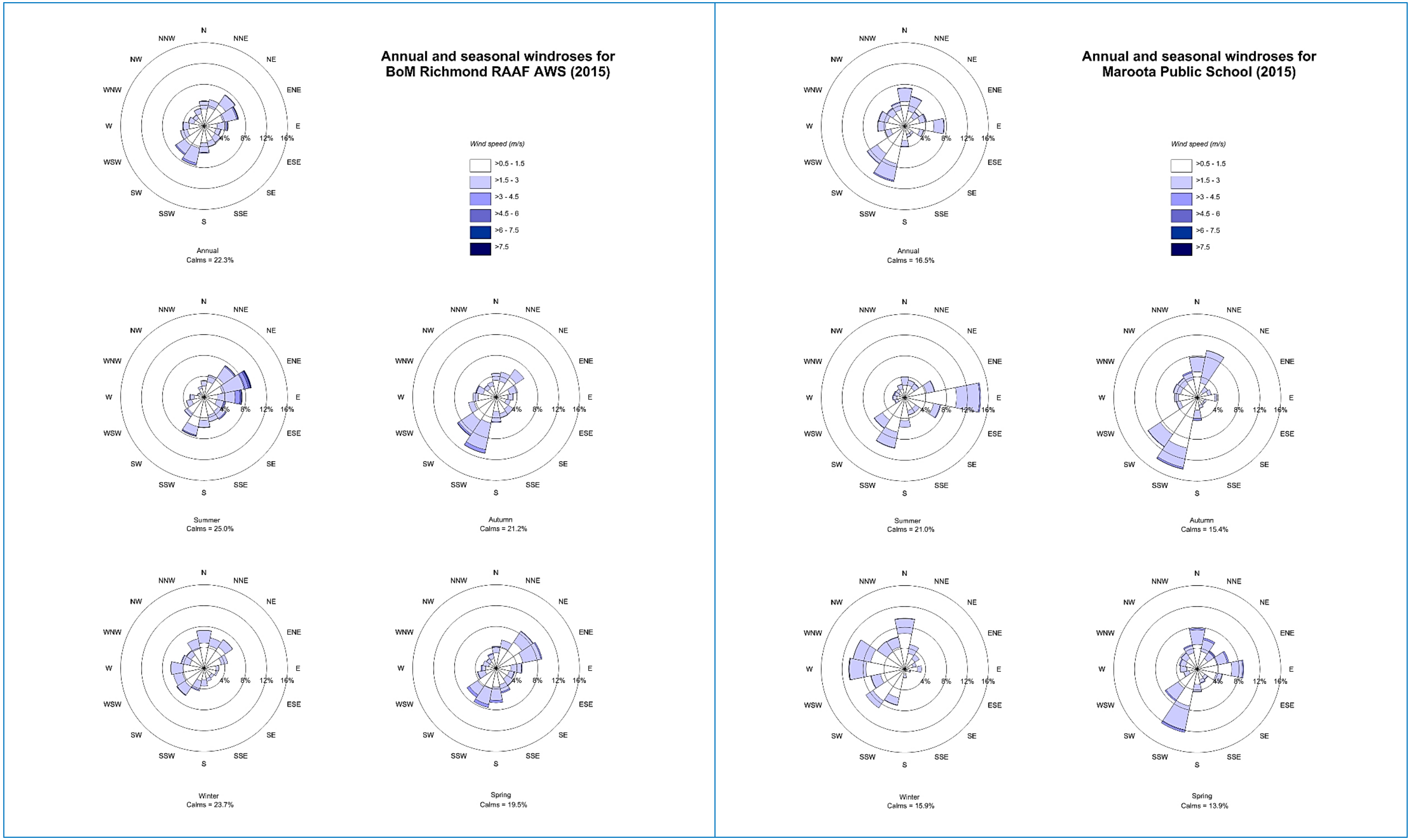


Figure 5.1: Windroses for 2015 (Left: BoM Richmond RAAF AWS, Right: Maroota Public School)

5.2.3 Atmospheric Stability

An important aspect of pollutant dispersion is the level of turbulence in the lowest 1 km or so of the atmosphere, known as the planetary boundary layer (PBL). Turbulence controls how effectively a plume is diffused into the surrounding air and hence diluted. It acts by increasing the cross-sectional area of the plume due to random motions. With stronger turbulence, the rate of plume diffusion increases. Weak turbulence limits diffusion and contributes to high plume concentrations downwind of a source.

Turbulence is generated by both thermal and mechanical effects to varying degrees. Thermally driven turbulence occurs when the surface is being heated, in turn transferring heat to the air above by convection. Mechanical turbulence is caused by the frictional effects of wind moving over the earth's surface, and depends on the roughness of the surface as well as the flow characteristics.

Turbulence in the boundary layer is influenced by the vertical temperature gradient, which is one of several indicators of stability. Plume models use indicators of atmospheric stability in conjunction with other meteorological data to estimate the dispersion conditions in the atmosphere.

Stability can be described across a spectrum ranging from highly unstable through neutral to highly stable. A highly unstable boundary layer is characterised by strong surface heating and relatively light winds, leading to intense convective turbulence and enhanced plume diffusion. At the other extreme, very stable conditions are often associated with strong temperature inversions and light winds, which commonly occur under clear skies at night and in the early morning. Under these conditions plumes can remain relatively undiluted for considerable distances downwind. Neutral conditions are linked to windy and/or cloudy weather, and short periods around sunset and sunrise, when surface rates of heating or cooling are very low.

The stability of the atmosphere plays a large role in determining the dispersion of a plume and it is important to have it correctly represented in dispersion models. Current air quality dispersion models (such as AERMOD and CALPUFF) use the Monin-Obukhov Similarity Theory (MOST) to characterise turbulence and other processes in the PBL. One of the measures of the PBL is the Monin-Obukhov length (L), which approximates the height at which turbulence is generated equally by thermal and mechanical effects (**Seinfeld and Pandis 2006**). It is a measure of the relative importance of mechanical and thermal forcing on atmospheric turbulence.

Because values of L diverge to + and - infinity as stability approaches neutral from the stable and unstable sides, respectively, it is often more convenient to use the inverse of L (i.e., 1/L) when describing stability.

Figure 5.2 shows the hourly averaged 1/L for the site computed from all data in the AERMET surface file. Based on **Table 5.2** this plot indicates that the PBL is stable overnight and becomes unstable as radiation from the sun heats the surface layer of the atmosphere and drives convection. The changes from positive to negative occur at the shifts between day and night. This indicates that the diurnal patterns of stability are realistic.

Table 5.2: Inverse of the Monin-Obukhov length L with respect to atmospheric stability

1/L	Atmospheric Stability
Negative	Unstable
Zero	Neutral
Positive	Stable

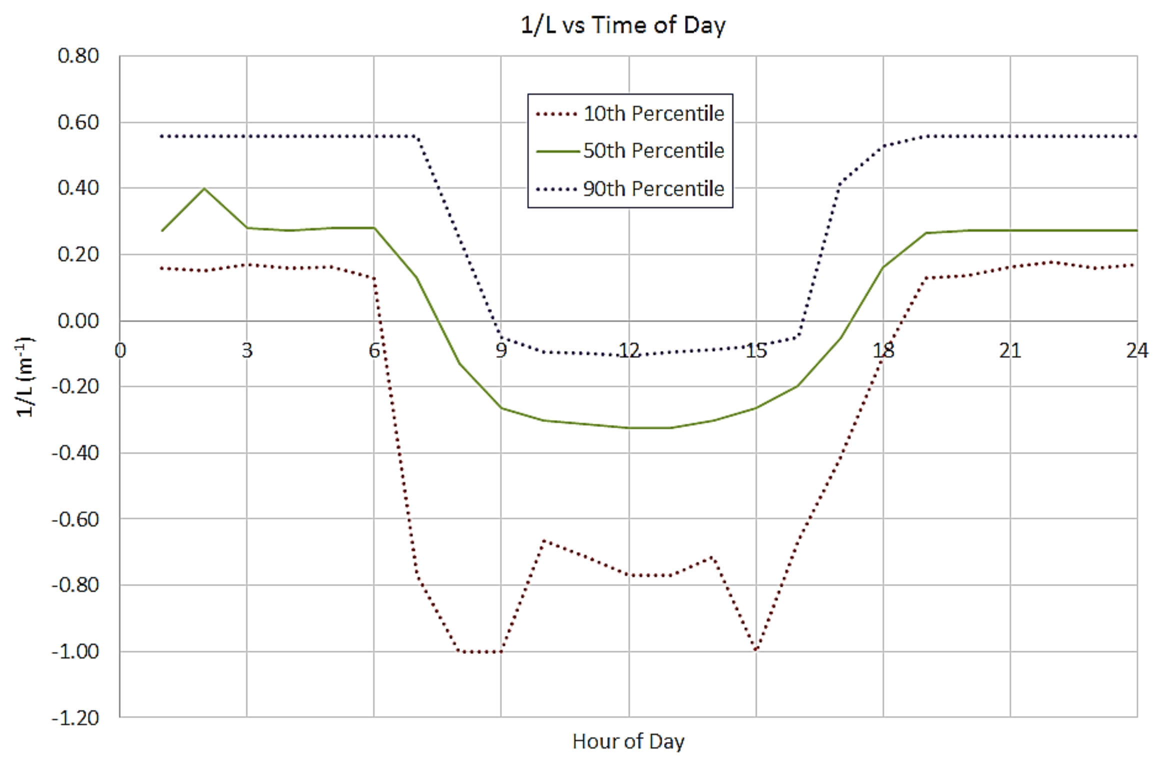


Figure 5.2: Annual statistics of 1/L by hour of the day

Figure 5.3 shows the variations in stability over the year by hour of the day, with reference to the widely known Pasquill-Gifford classes of stability. The relationship between L and stability classes is based on values derived by **Golder (1972)** set out in **NSW DEC (2005)**. Note that the reference to stability categories here is only for convenience in describing stability. The model uses calculated values of L across a continuum.

Figure 5.3 shows that stable and very stable conditions occur for about 60% of the time, which is typical for inland locations that regularly experience temperature inversions at night. Atmospheric instability increases during the day and reaches a peak around noon as solar-driven convective energy peaks. A stable atmosphere is prevalent during the night. These profiles indicate that pollutant dispersion is most effective during the daytime and least effective at night.

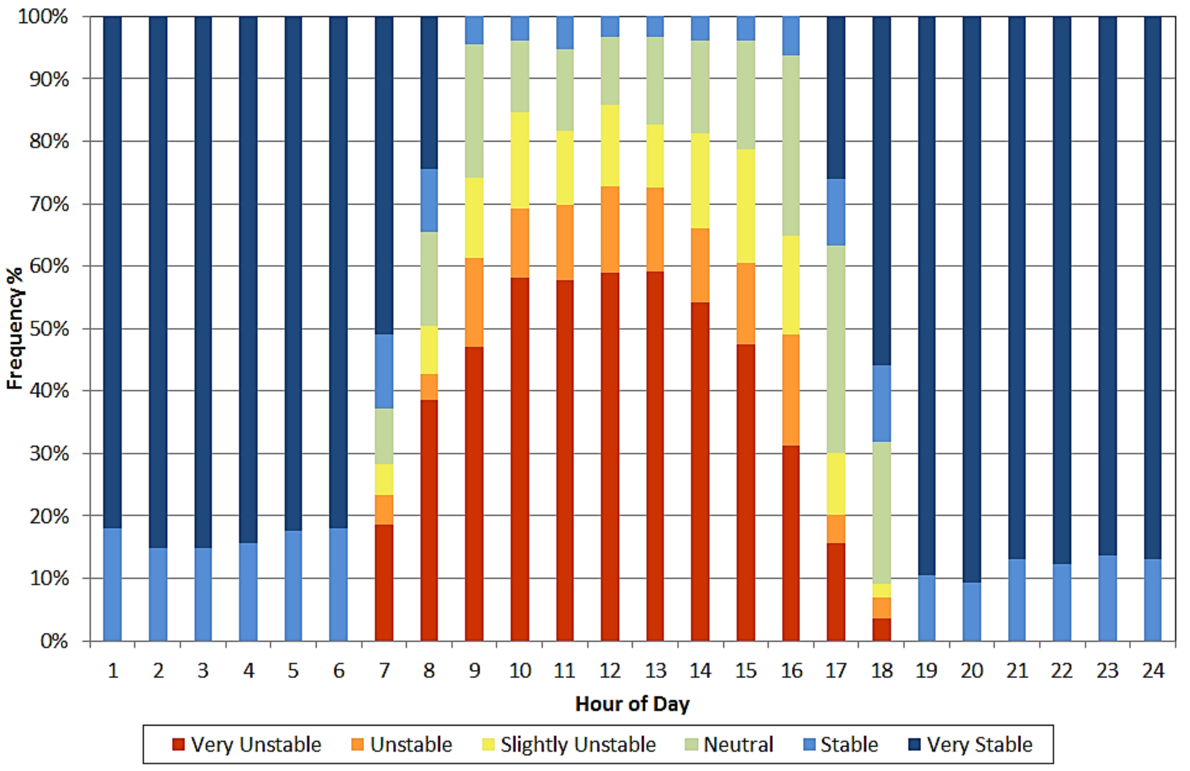


Figure 5.3: Annual distribution of stability type by hour of the day

5.3 Existing Air Quality

Air quality standards and goals refer to pollutant levels which include the contribution from proposed projects as well as other sources. To fully assess impacts against all the relevant air quality standards and goals it is necessary to have information or estimates on existing dust concentration and deposition levels in the area in which the project is likely to contribute to these levels.

5.3.1 PM Concentrations

As part of Dixon Sand Environment Protection License (EPL) No 12513, they are required to measure PM_{10} at Maroota Public School. **Figure 5.4** shows the PM_{10} concentrations measured by a Tapered Element Oscillating Microbalance (TEOM) at Maroota Public School, the annual and 24-hour average assessment criterion (see **Section 4.1**).

Also shown is the Dixon Sand "investigation limit' stated in EPL 12513 that states:

- if any rolling 24-hour average PM_{10} result measured is found to be greater than 42 µg/m³ and the prevailing wind at the site is between 180° and 240°, Dixon Sand must immediately implement a series of dust mitigation measures.

The 24-hour average PM_{10} concentrations have exceeded the assessment criteria on seven occasions during the period from March 2013 to Dec 2015. Six of the seven exceedances all occurred between September and December 2013. There was widespread and severe bushfire activity across eastern NSW during this period which saw 19 areas declared as natural disaster areas (**BoM, 2013**) and will have contributed significantly to measured dust levels at that time.

Further, the exceedance in May 2015 was correlated to a dust storm event from fires at nearby residents (**Dixon, 2015**). The annual average for the modelling period and that used to represent background PM_{10} for the cumulative assessment is 13 µg/m³.

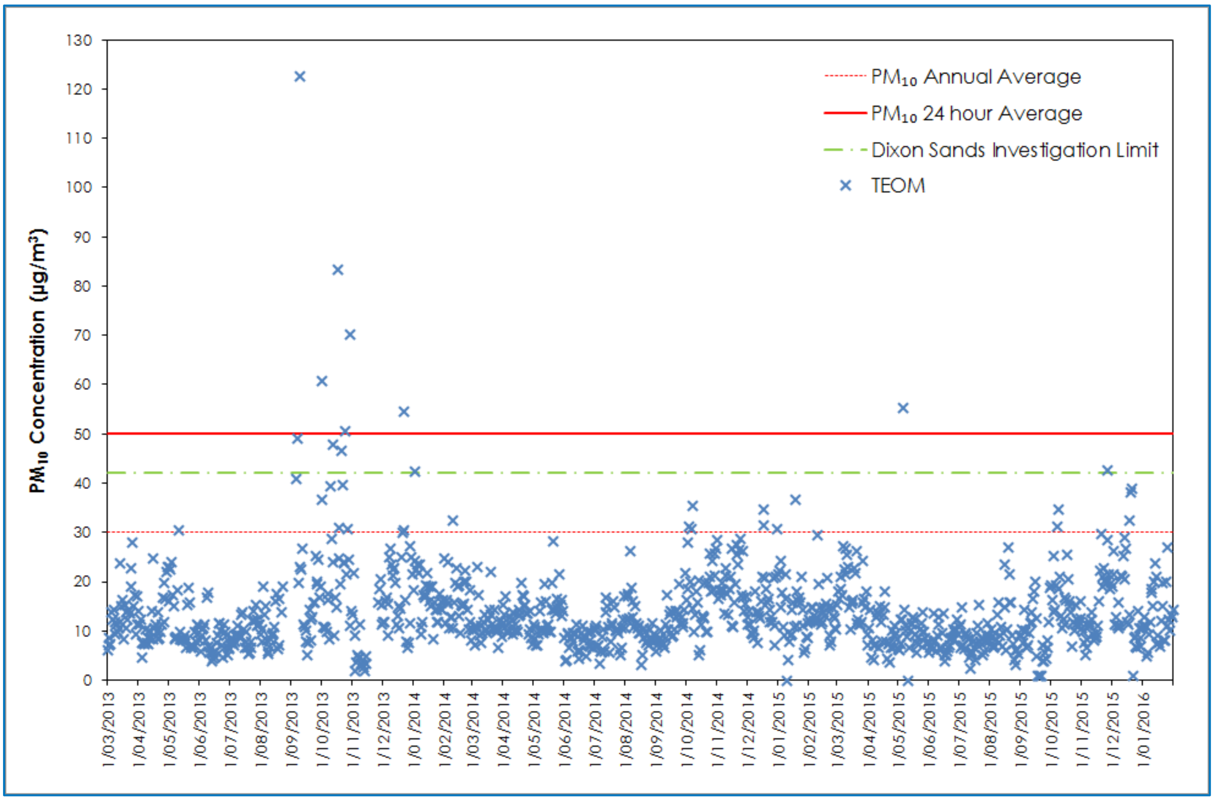


Figure 5.4: Measured PM_{10} for Maroota Public School TEOM

There are no $PM_{2.5}$ measurements near the site and the closest EPA sites are at Vineyard, Richmond and Wyong. **Table 5.3** presents the annual averages of both the PM_{10} and $PM_{2.5}$ concentrations measured at these sites.

The average PM_{10} concentrations recorded across all three sites is 16 µg/m³ and the average $PM_{2.5}$ concentration is 6.2 µg/m³. Given that the surrounding EPA sites PM_{10} concentrations are a similar level to the TEOM at Maroota, a PM_{10} background level of 13 µg/m³ has been adopted for cumulative assessment. The average of the two EPA sites $PM_{2.5}$ of 6.2 µg/m³ will be adopted for the cumulative $PM_{2.5}$ assessment.

Table 5.3: PM_{10} and $PM_{2.5}$ Concentrations at EPA Monitoring Sites

Site	2010	2011	2012	2013	2014	2015	2016[1]
				PM_{10}			
Wyong	-	-	21.8	16.6	15.1	14.9	18.5
Richmond	13.1	13.2	15.1	17.3	15.4	12.8	16.8
Vineyard	14.5	14.0	14.4	16.1	16.3	15.9	18.8
				$PM_{2.5}$			
Wyong			7.3	6.7	5.5	5.2	5.6
Richmond	4.2	4.7	5.3	8.3	6.7	7.7	7.0

[1] Data presented for January – 15 March 2016

5.3.2 TSP Concentrations

There are no measurements of TSP available for the site. Estimates of annual average TSP concentrations can be made from the PM_{10} measurements by assuming that 40% of the TSP is PM_{10}. This relationship was obtained from data collected by co-located TSP and PM_{10} monitors operated for long periods of time in the Hunter Valley (**NSW Minerals Council, 2000**). Although this ratio is based on Hunter Valley data, in the absence of site specific data this provides an indicative estimate of the ambient TSP. Use of this relationship on the adopted PM_{10} annual average of 13 µg/m³ gives an existing annual average TSP concentration of approximately 32.5 µg/m³.

5.3.3 Dust Deposition

Table 5.1 shows annual average insoluble solids deposition rates from Dixon Sand's dust deposition gauge (Haerses Road Quarry) (**Dixon Sand, 2015**). PF Formation operates sand quarries in close proximity to the proposed Haerses Road site, and the four dust deposition gauges (Maroota Public School, Hitchcock Rd and Jurd's House) have been included to provide a more thorough data set (**PF Formation, 2015**). The locations of the dust deposition gauges is presented in **Figure 5.5**.

An annual average dust deposition level above 4 g/m²/month indicates a level of air quality unsuitable for residential purposes. Levels measured are affected by dust from other sand extraction activities in the area as well as other sources of dust such as agricultural activities normally expected in rural areas.

Using a conservative estimate, the background dust deposition level for the modelling year of 2.1 g/m²/month was determined using the average of all four sites presented in **Table 5.1**.

Table 5.1: Annual Average Dust Deposition Data (g/m²/month)

Year	Haerses Road Quarry	Maroota Public School	Hitchcock Rd	Jurd's House
2015	1.2[1]	2.4	2.6	2.2

[1] August and September results excluded from the annual average as the results for these months were outliers in the data. It is stated in the EPL reports that Dixon Quarry did not operate for the majority of these monitoring periods. It is suggested that the high result could be attributed to agricultural burn offs, grass slashing by the resident and/or clean up in the vicinity of the static dust gauge.

Figure 5.5: Dust Deposition Monitoring Locations

5.3.4 Background Values

In summary, for the purposes of assessing potential air quality impacts, the following existing air quality levels are assumed for assessment against the long-term criteria. PM_{10} is also assessed against a short-term (24-hour) criterion which is assessed separately in **Section 4**.

- Annual average PM_{10} concentration of 13 µg/m^3.
- Annual average $PM_{2.5}$ concentration of 6.2 µg/m^3.
- Annual average TSP concentration of 32.5 µg/m^3.
- Annual average dust deposition of 2.1 g/m^2/month.

6 EMISSIONS TO AIR

6.1 Modelling Approach

The overall approach to the assessment generally follows the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (**NSW DEC, 2005**) using the Level 2 assessment methodology. The Approved Methods specify how assessments based on the use of air dispersion models should be completed. They include guidelines for the preparation of meteorological data to be used in dispersion models and the relevant air quality criteria for assessing the significance of predicted concentration and deposition rates from projects.

6.1.1 Modelling System

AERMOD was chosen as the most suitable model due to the source types, location of nearest receivers and nature of local topography. AERMOD is the US-EPA's recommended steady-state plume dispersion model for regulatory purposes and it is an accepted model of the NSW EPA. AERMOD replaced the Industrial Source Complex (ISC) model for regulatory purposes in the US in December 2006 as it provides more realistic results. Ausplume, a steady state Gaussian plume dispersion model developed by the Victorian EPA and frequently used in Australia for simple near-field applications is based on ISC, which has now been replaced by AERMOD.

A significant feature of AERMOD is the Pasquill-Gifford stability based dispersion is replaced with a turbulence-based approach that uses the Monin-Obukhov length scale to account for the effects of atmospheric turbulence based dispersion.

The AERMOD system includes AERMET, used for the preparation of meteorological input files and AERMAP, used for the preparation of terrain data.

Terrain data was sourced from NASA's Shuttle Radar Topography Mission (SRTM) Data (3 arc-second (~90m) resolution) and processed within AERMAP to create the necessary input files.

AERMET requires surface and upper air meteorological data as input. Surface data was sourced from the Maroota Public School weather station and cloud data from TAPM. Appropriate values for three surface characteristics are required for AERMET as follows:

- Surface roughness, which is the height at which the mean horizontal wind speed approaches zero, based on a logarithmic profile.
- Bowen ratio, which is an indicator of surface moisture.
- Albedo, which is an indicator of reflectivity of the surface.

Values of surface roughness, Bowen ratio and albedo were determined based on a review of aerial photography for a radius of 3 km centred on the quarry site. Default values for cultivated land was chosen for the entire area.

The configuration of the model and the inputs used are explained below. A summary of all the AERMOD inputs is provided in **Appendix A**.

6.2 Operational Scenarios

Plant at the Haerses Road site is mobile and would operate either within the existing approved extraction area or within the proposed additional extraction area. Plant and activities would not occur within both areas of the site at the same time.

There is potential for dry processing operations (screening and crushing) to occur in the extraction pits themselves, before the material is hauled to the wet processing area and then to either the central processing plant at the Old Northern Road site or directly to market. Although the scenario where dry processing will occur directly prior to wet processing is expected to be the predominant use at the quarry, it was considered suitable to assess both.

The operational scenarios are presented in **Table 6.1**.

Table 6.1: Operational Scenarios

Description	Scenario
Dry processing **outside** extraction cells	1
Dry processing **inside** extraction cells	2

6.3 Emissions Summary

Dust emissions during operation of the modified quarry have been estimated based on activities and equipment that would be operating at the site, as follows:

- Dozer/excavator/loader clearing vegetation/topsoil;
- Dozer/loader for overburden shaping;
- Excavator/loader for excavation of raw material;
- Front End Loader stockpiling raw material;
- Front End Loader loading road trucks in extraction cells;
- Hauling on unsealed roads from extraction cells to sealed road ;
- Hauling product on sealed access road to processing plant and/or to market;
- Dry processing (crushing/screening); and
- Wind erosion from active extraction cells, areas yet to be rehabilitated and active stockpiles.

The estimated dust emissions for annual average production are presented in **Table 6.2** and worst case maximum daily production in **Table 6.3**. Note that the emission estimations presented are for Scenario 1. However the total emissions are comparable between the scenarios, with only the order of activities varying, therefore it was not considered necessary to present both in this section.

The full emissions inventories for general operations, worst case operations and source locations are presented in **Appendix B**.

The maximum daily production scenario (worst case) is modelled based on maximum product transport of 850 tonnes per day. The maximum daily emissions are applied for each day of the modelled year so that a full range of meteorological conditions can be tested for this scenario to determine the worst-case 24-hour concentrations. This does not represent a realistic estimate of annual dust emissions, although they could potentially reach these emission levels on a daily basis.

Most activities and emissions (with the exception of wind erosion) are assumed to occur between 7am and 6pm, modelled as seven days per week to be conservative[a]. Hauling also occurs between the

[a] Note, the site will only operate six days a week, but the dispersion modelling has conservatively it will operate seven days a week

hours of 7am and 6pm and wind erosion is assumed to occur 24 hours per day. TSP, PM_{10} and $PM_{2.5}$ emission rates were calculated using emission factors derived from **US EPA (1995)** (see **Appendix B**).

Table 6.2: Estimated Dust Emissions for Scenario 1 – Annual Average

ACTIVITY	TSP (kg/y)	PM10 (kg/y)	PM2.5 (kg/y)
Dozer stripping topsoil (from pit 5)	9,312	2,271	978
FEL Loading sand to trucks (from pit 5)	53	25	4
Hauling from pit 5 to Processing Area (unsealed)	7,423	2,004	200
FEL Unloading sand to stockpile	53	25	4
FEL Loading sand from stockpile	53	25	4
FEL Unloading sand to Dry Processing	53	25	4
Crusher (uncontrolled)	4,875	1,875	146
Transfer (Crusher to Screen) [conveyor transfer point]	53	25	4
Screen (uncontrolled)	3,125	1,075	94
Transfer (Screen to Wet Processing) [conveyor transfer point]	53	25	4
Wet Processing (no expected emissions)	0	0	0
FEL Loading sand from Product Stockpile to haul trucks	15	7	1
Hauling out of Site (unsealed)	7,204	1,945	194
Hauling out of Site (sealed)	1,630	313	76
Wind Erosion - Extraction Area (pit 3)	2,628	1,314	197
Wind Erosion - (pit 4)	4,380	2,190	329
Wind Erosion - (pit 5)	4,468	2,234	335
Wind Erosion - Extraction Stockpile	123	61	9
Wind Erosion - Pre Processing Stockpile	123	61	9
Wind Erosion - Product Stockpile	123	61	9
TOTAL EMISSIONS	**45,743**	**15,561**	**2,600**

Table 6.3: Estimated Annual Dust Emissions for Scenario 1 Based on Maximum Daily Production Scenario (Worst Case)

ACTIVITY	TSP (kg/y)	PM10 (kg/y)	PM2.5 (kg/y)
Dozer stripping topsoil (from pit 5)	9,312	2,271	978
FEL Loading sand to trucks (from pit 5)	65	31	5
Hauling from pit 5 to Processing Area (unsealed)	9,212	2,487	249
FEL Unloading sand to stockpile	65	31	5
FEL Loading sand from stockpile	65	31	5
FEL Unloading sand to Dry Processing	65	31	5
Crusher (uncontrolled)	6,050	2,327	181
Transfer (Crusher to Screen) [conveyor transfer point]	65	31	5
Screen (uncontrolled)	3,878	1,334	116
Transfer (Screen to Wet Processing) [conveyor transfer point]	65	31	5
Wet Processing (no expected emissions)	0	0	0
FEL Loading sand from Product Stockpile to haul trucks	18	9	1
Hauling out of Site (unsealed)	8,940	2,413	241
Hauling out of Site (sealed)	2,023	388	94
Wind Erosion - Extraction Area (pit 3)	2,628	1,314	197
Wind Erosion - (pit 4)	4,380	2,190	329
Wind Erosion - (pit 5)	4,468	2,234	335
Wind Erosion - Extraction Stockpile	123	61	9
Wind Erosion - Pre Processing Stockpile	123	61	9
Wind Erosion - Product Stockpile	123	61	9
TOTAL EMISSIONS	**51,669**	**17,337**	**2,777**

6.4 Proposed Dust Control Measures

The Modification will employ a number of best practice mitigation measures on-site to ensure that dust impacts are minimised.

Measures to be employed for the Modification include:

- Use of a water cart to control emissions from haul roads (unsealed).
- Enforcement of speed limits onsite.
- Progressive rehabilitation of exposed areas.
- Minimising drop height of material during truck loading and unloading where possible.
- Management of dust generating activities during unfavourable meteorological conditions.

7 OPERATIONAL PHASE IMPACT ASSESSMENT

The modelling predictions for the Modification are presented in the sections below. The contour plots are indicative of the concentrations that could potentially be reached under the new conditions modelled. It is important to note that the isopleth figures are presented to provide a visual representation of the predicted impacts. To produce the isopleths, it is necessary to make interpolations, and as a result the isopleths will not always match exactly with predicted impacts at any specific location.

A summary of the predicted pollutant concentrations at each of the assessment locations is presented in **Table 7.1** through **Table 7.4**. The results indicate that the incremental increases from the Modification on an annual and worst case operational basis, when added to the background concentrations outlined in **Section 5.3**, are below the respective EPA criteria for particulate matter and dust deposition.

The cumulative 24-hour average concentrations are discussed further in **Section 7.2**.

Table 7.1: Predicted incremental and cumulative ground level concentrations for Scenario 1 (Annual Operations)

ID	PM_{10}				$PM_{2.5}$				TSP		Dust Deposition	
	24 hour		Annual		24 hour		Annual		Annual		Annual	
	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative
Units	µg/m³										g/m²/month	
Impact Assessment Criteria	N/A	50	N/A	30	N/A	25	N/A	8	N/A	90	2	4
R1	9.2	22.2	0.2	13.2	1.3	7.5	0.1	6.3	0.5	33	0.02	2.12
R2	6.8	19.8	0.4	13.4	1.1	7.3	0.1	6.3	1.3	33.8	0.04	2.14
R3	7.1	20.1	0.4	13.4	1.4	7.6	0.1	6.3	0.5	33	0.02	2.12
R4	4.2	17.2	0.3	13.3	1.2	7.4	0.1	6.3	0.4	32.9	0.01	2.11
R5	8.3	21.3	0.7	13.7	4.1	10.3	0.2	6.4	0.6	33.1	0.01	2.11
R6	25.7	38.7	1.4	14.4	5.7	11.9	0.4	6.6	1.4	33.9	0.04	2.14
R7	5.6	18.6	0.6	13.6	2.2	8.4	0.2	6.4	0.6	33.1	0.02	2.12
R8	18.7	31.7	1.3	14.3	3.5	9.7	0.4	6.6	1.5	34	0.05	2.15
R9	24.6	37.6	1.3	14.3	4.2	10.4	0.4	6.6	1.4	33.9	0.04	2.14
R10	25.8	38.8	1	14	4.5	10.7	0.3	6.5	1	33.5	0.03	2.13
R11	30.8	43.8	1.3	14.3	5.4	11.6	0.4	6.6	1.3	33.8	0.04	2.14
R12	10.5	23.5	0.2	13.2	1.6	7.8	0.1	6.3	0.6	33.1	0.02	2.12
R13	10.1	23.1	0.2	13.2	1.5	7.7	0	6.2	0.5	33	0.02	2.12
R14	5.1	18.1	0.2	13.2	1.1	7.3	0.1	6.3	0.4	32.9	0.01	2.11
R15	10.1	23.1	0.2	13.2	1.5	7.7	0	6.2	0.5	33	0.02	2.12
R16	2.8	15.8	0.2	13.2	0.8	7	0.1	6.3	0.3	32.8	0.01	2.11
R17	21.8	34.8	0.7	13.7	3.8	10	0.2	6.4	0.5	33	0.01	2.11
R18	6.9	19.9	0.4	13.4	2.1	8.3	0.1	6.3	0.3	32.8	0.01	2.11
R19	9.1	22.1	0.3	13.3	1.7	7.9	0.1	6.3	0.3	32.8	0.01	2.11
R20	22.1	35.1	0.3	13.3	5.4	11.6	0.1	6.3	0.3	32.8	0.01	2.11
D1	8.7	21.7	0.2	13.2	1.4	7.6	0	6.2	0.5	33	0.02	2.12
PF1	4	17	0.1	13.1	0.6	6.8	0	6.2	0.4	32.9	0.01	2.11
PF2	4.5	17.5	0.2	13.2	0.7	6.9	0	6.2	0.5	33	0.02	2.12
PF3	6.2	19.2	0.4	13.4	1	7.2	0.1	6.3	0.7	33.2	0.02	2.12

Table 7.2: Predicted incremental and cumulative ground level concentrations for Scenario 1 (Worst Case Day Operations)

ID	PM_{10}				$PM_{2.5}$				TSP		Dust Deposition	
	24 hour		Annual		24 hour		Annual		Annual		Annual	
	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative
Units	µg/m³										g/m²/month	
Impact Assessment Criteria	**N/A**	**50**	**N/A**	**30**	**N/A**	**25**	**N/A**	**8**	**N/A**	**90**	**2**	**4**
R1	9.8	22.8	0.3	13.3	1.4	7.6	0.1	6.3	0.6	33.1	0.02	2.12
R2	7	20	0.5	13.5	1.2	7.4	0.1	6.3	1.5	34	0.04	2.14
R3	7.2	20.2	0.4	13.4	1.6	7.8	0.1	6.3	0.6	33.1	0.02	2.12
R4	4.8	17.8	0.3	13.3	1.3	7.5	0.1	6.3	0.5	33	0.01	2.11
R5	9.7	22.7	0.7	13.7	4.4	10.6	0.2	6.4	0.6	33.1	0.02	2.12
R6	26.4	39.4	1.5	14.5	6.2	12.4	0.4	6.6	1.5	34	0.04	2.14
R7	6.7	19.7	0.6	13.6	2.3	8.5	0.2	6.4	0.7	33.2	0.02	2.12
R8	18.8	31.8	1.4	14.4	3.5	9.7	0.4	6.6	1.6	34.1	0.05	2.15
R9	24.6	37.6	1.4	14.4	4.3	10.5	0.4	6.6	1.5	34	0.04	2.14
R10	25.8	38.8	1.1	14.1	4.5	10.7	0.3	6.5	1.1	33.6	0.03	2.13
R11	30.8	43.8	1.4	14.4	5.4	11.6	0.4	6.6	1.4	33.9	0.04	2.14
R12	10.6	23.6	0.3	13.3	1.6	7.8	0.1	6.3	0.7	33.2	0.02	2.12
R13	10.4	23.4	0.3	13.3	1.6	7.8	0.1	6.3	0.6	33.1	0.02	2.12
R14	5.7	18.7	0.3	13.3	1.3	7.5	0.1	6.3	0.4	32.9	0.01	2.11
R15	10.4	23.4	0.3	13.3	1.6	7.8	0.1	6.3	0.6	33.1	0.02	2.12
R16	3.4	16.4	0.2	13.2	1	7.2	0.1	6.3	0.3	32.8	0.01	2.11
R17	21.9	34.9	0.7	13.7	3.8	10	0.2	6.4	0.6	33.1	0.01	2.11
R18	7.7	20.7	0.4	13.4	2.3	8.5	0.1	6.3	0.3	32.8	0.01	2.11
R19	9.3	22.3	0.4	13.4	1.7	7.9	0.1	6.3	0.4	32.9	0.01	2.11
R20	22.1	35.1	0.3	13.3	5.4	11.6	0.1	6.3	0.3	32.8	0.01	2.11
D1	8.7	21.7	0.2	13.2	1.4	7.6	0.1	6.3	0.6	33.1	0.02	2.12
PF1	4	17	0.2	13.2	0.6	6.8	0	6.2	0.4	32.9	0.01	2.11
PF2	4.6	17.6	0.2	13.2	0.7	6.9	0	6.2	0.5	33	0.02	2.12
PF3	6.2	19.2	0.4	13.4	1.2	7.4	0.1	6.3	0.8	33.3	0.02	2.12

Table 7.3: Predicted incremental and cumulative ground level concentrations for Scenario 2 (Annual Operations)

ID	PM_{10}				$PM_{2.5}$				TSP		Dust Deposition	
	24 hour		Annual		24 hour		Annual		Annual		Annual	
	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative
Units	µg/m³										g/m²/month	
Impact Assessment Criteria	**N/A**	**50**	**N/A**	**30**	**N/A**	**25**	**N/A**	**8**	**N/A**	**90**	**2**	**4**
R1	7.9	20.9	0.2	13.2	1.2	7.4	0.1	6.3	0.6	33.1	0.02	2.12
R2	6.5	19.5	0.4	13.4	1	7.2	0.1	6.3	1.3	33.8	0.04	2.14
R3	7.1	20.1	0.3	13.3	1.3	7.5	0.1	6.3	0.6	33.1	0.02	2.12
R4	3.9	16.9	0.3	13.3	1.2	7.4	0.1	6.3	0.4	32.9	0.01	2.11
R5	7.2	20.2	0.7	13.7	3.5	9.7	0.2	6.4	0.7	33.2	0.02	2.12
R6	27.4	40.4	2	15	6.1	12.3	0.5	6.7	1.8	34.3	0.05	2.15
R7	6.1	19.1	0.6	13.6	2.5	8.7	0.2	6.4	0.7	33.2	0.02	2.12
R8	18.9	31.9	1.6	14.6	4	10.2	0.4	6.6	2	34.5	0.06	2.16
R9	24.7	37.7	1.6	14.6	5	11.2	0.4	6.6	1.8	34.3	0.05	2.15
R10	25.8	38.8	1.2	14.2	4.5	10.7	0.3	6.5	1.2	33.7	0.04	2.14
R11	30.9	43.9	1.5	14.5	5.4	11.6	0.4	6.6	1.5	34	0.04	2.14
R12	10.5	23.5	0.3	13.3	1.6	7.8	0.1	6.3	0.6	33.1	0.02	2.12
R13	9.7	22.7	0.3	13.3	1.5	7.7	0.1	6.3	0.6	33.1	0.02	2.12
R14	5.1	18.1	0.2	13.2	1	7.2	0.1	6.3	0.4	32.9	0.01	2.11
R15	9.7	22.7	0.3	13.3	1.5	7.7	0.1	6.3	0.6	33.1	0.02	2.12
R16	2.7	15.7	0.2	13.2	0.7	6.9	0	6.2	0.3	32.8	0.01	2.11
R17	21.8	34.8	0.7	13.7	3.8	10	0.2	6.4	0.5	33	0.01	2.11
R18	6	19	0.4	13.4	1.8	8	0.1	6.3	0.3	32.8	0.01	2.11
R19	8.9	21.9	0.3	13.3	1.6	7.8	0.1	6.3	0.3	32.8	0.01	2.11
R20	22.1	35.1	0.3	13.3	5.4	11.6	0.1	6.3	0.3	32.8	0.01	2.11
D1	8.8	21.8	0.2	13.2	1.4	7.6	0	6.2	0.6	33.1	0.02	2.12
PF1	4.1	17.1	0.1	13.1	0.6	6.8	0	6.2	0.4	32.9	0.01	2.11
PF2	4.6	17.6	0.2	13.2	0.7	6.9	0	6.2	0.5	33	0.02	2.12
PF3	6.3	19.3	0.3	13.3	1	7.2	0.1	6.3	0.7	33.2	0.02	2.12

Table 7.4: Predicted incremental and cumulative ground level concentrations for Scenario 2 (Worst Case Day Operations)

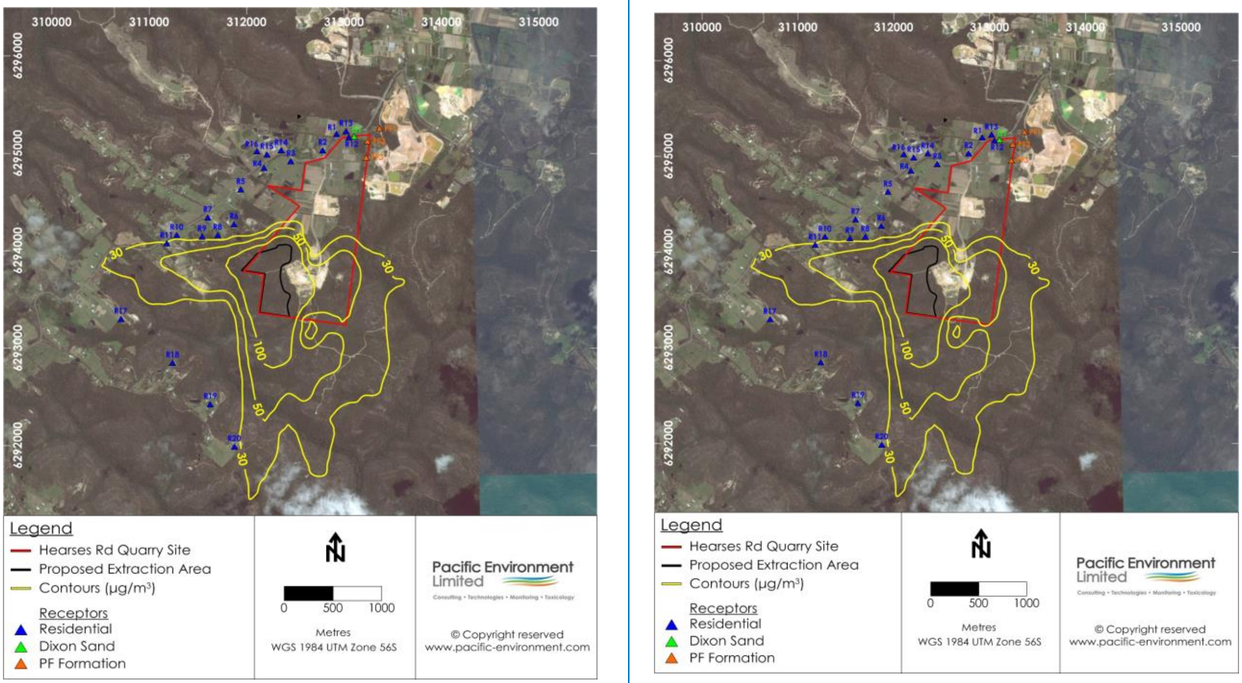
ID	PM_{10}				$PM_{2.5}$				TSP		Dust Deposition	
	24 hour		Annual		24 hour		Annual		Annual		Annual	
	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative
Units	µg/m³										g/m²/month	
Impact Assessment Criteria	N/A	50	N/A	30	N/A	25	N/A	8	N/A	90	2	4
R1	8.2	21.2	0.3	13.3	1.2	7.4	0.1	6.3	0.7	33.2	0.02	2.12
R2	6.7	19.7	0.5	13.5	1.1	7.3	0.1	6.3	1.6	34.1	0.05	2.15
R3	7.2	20.2	0.4	13.4	1.3	7.5	0.1	6.3	0.7	33.2	0.02	2.12
R4	4.4	17.4	0.3	13.3	1.2	7.4	0.1	6.3	0.5	33	0.01	2.11
R5	8.1	21.1	0.8	13.8	3.6	9.8	0.2	6.4	0.8	33.3	0.02	2.12
R6	28.5	41.5	2.2	15.2	6.6	12.8	0.5	6.7	1.9	34.4	0.05	2.15
R7	7.3	20.3	0.7	13.7	2.6	8.8	0.2	6.4	0.8	33.3	0.02	2.12
R8	18.9	31.9	1.8	14.8	4.1	10.3	0.4	6.6	2.2	34.7	0.06	2.16
R9	24.8	37.8	1.8	14.8	5.2	11.4	0.4	6.6	2	34.5	0.06	2.16
R10	25.9	38.9	1.3	14.3	4.7	10.9	0.3	6.5	1.4	33.9	0.04	2.14
R11	30.9	43.9	1.7	14.7	5.4	11.6	0.4	6.6	1.6	34.1	0.04	2.14
R12	10.6	23.6	0.3	13.3	1.6	7.8	0.1	6.3	0.7	33.2	0.02	2.12
R13	10	23	0.3	13.3	1.5	7.7	0.1	6.3	0.7	33.2	0.02	2.12
R14	5.2	18.2	0.2	13.2	1	7.2	0.1	6.3	0.4	32.9	0.01	2.11
R15	10	23	0.3	13.3	1.5	7.7	0.1	6.3	0.7	33.2	0.02	2.12
R16	3.1	16.1	0.2	13.2	0.8	7	0.1	6.3	0.3	32.8	0.01	2.11
R17	21.9	34.9	0.7	13.7	3.8	10	0.2	6.4	0.6	33.1	0.01	2.11
R18	6.2	19.2	0.4	13.4	1.9	8.1	0.1	6.3	0.4	32.9	0.01	2.11
R19	9.1	22.1	0.4	13.4	1.7	7.9	0.1	6.3	0.4	32.9	0.01	2.11
R20	22.1	35.1	0.4	13.4	5.4	11.6	0.1	6.3	0.3	32.8	0.01	2.11
D1	8.8	21.8	0.3	13.3	1.4	7.6	0.1	6.3	0.7	33.2	0.02	2.12
PF1	4.1	17.1	0.2	13.2	0.6	6.8	0	6.2	0.4	32.9	0.01	2.11
PF2	4.7	17.7	0.2	13.2	0.7	6.9	0	6.2	0.6	33.1	0.02	2.12
PF3	6.4	19.4	0.4	13.4	1	7.2	0.1	6.3	0.8	33.3	0.02	2.12

7.1 Incremental Impact Assessment

7.1.1 Ground Level PM_{10} Concentrations

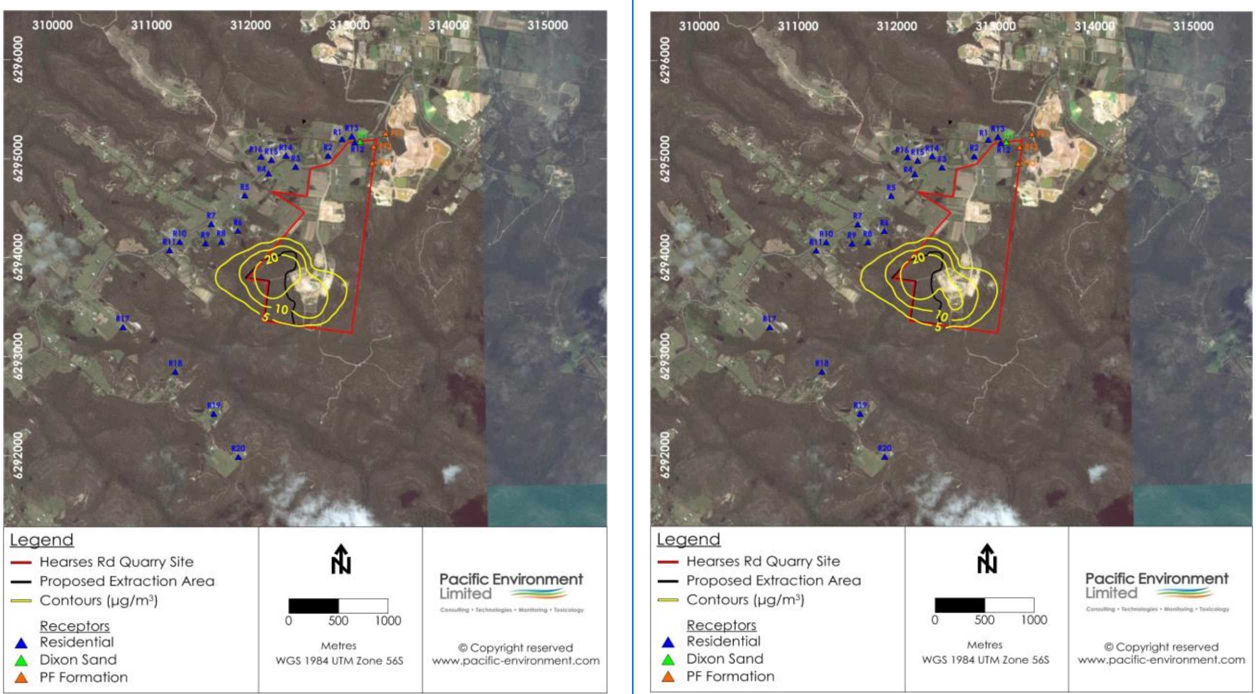
Contour plots for the predicted (glcs) of PM_{10} are presented in **Figure 7.1** and **Figure 7.2**. Predicted 24-hour and annual average PM_{10} are presented for the annual and worst case day operations. Note that the resultant contours for Scenario 2 are comparable to Scenario 1 and therefore they are not presented.

There are no privately owned receptors that are predicted to experience glcs of PM_{10} above the assessment criteria, due to emissions from the Modification only. The highest predicted glcs occur at receptor 11 (R11). At this location, the predicted incremental 24-hour PM_{10} concentration is 30.8 µg/m^3. The predicted annual average PM_{10} concentration at this receptor is 1.3 µg/m^3.



Annual Operations	Worst Case Day Operations

Figure 7.1: Maximum 24-Hour PM_{10} Concentration – Scenario 1



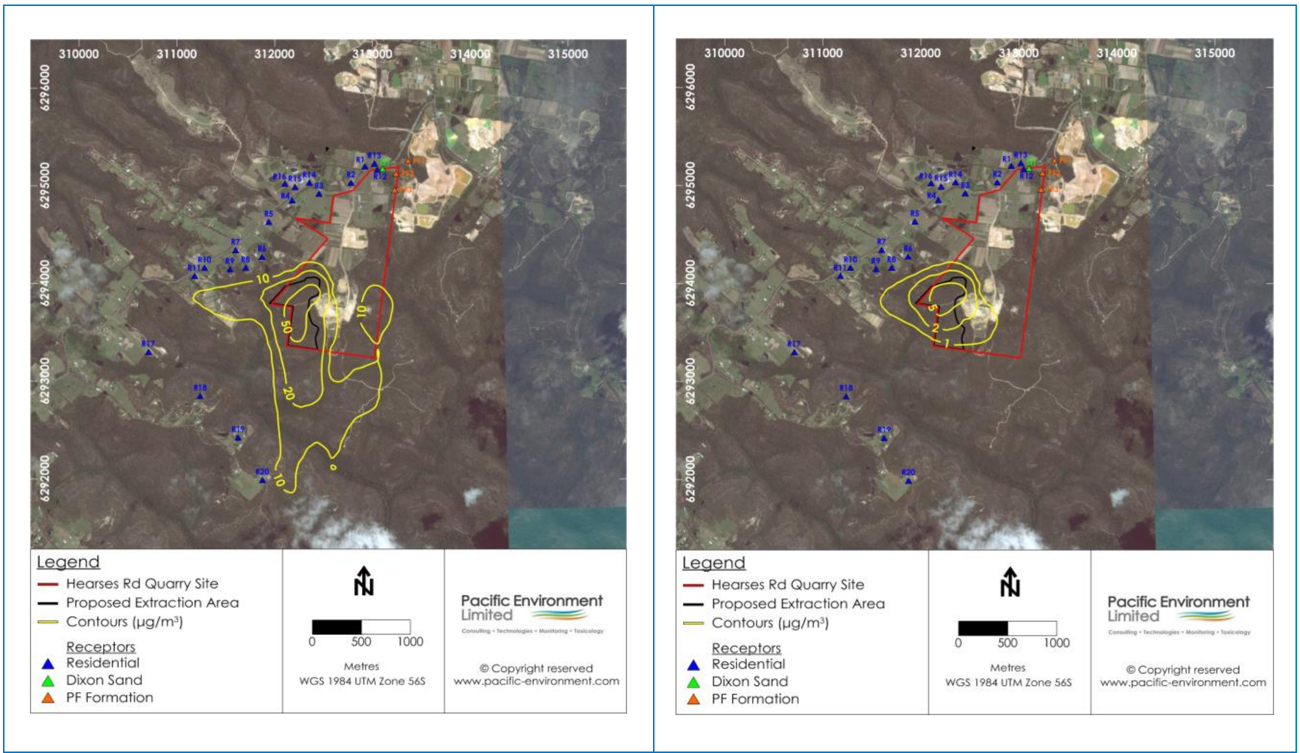
Annual Operations	Worst Case Day Operations

Figure 7.2: Incremental Annual Average PM_{10} Concentration – Scenario 1

7.1.2 Ground Level $PM_{2.5}$ Concentrations

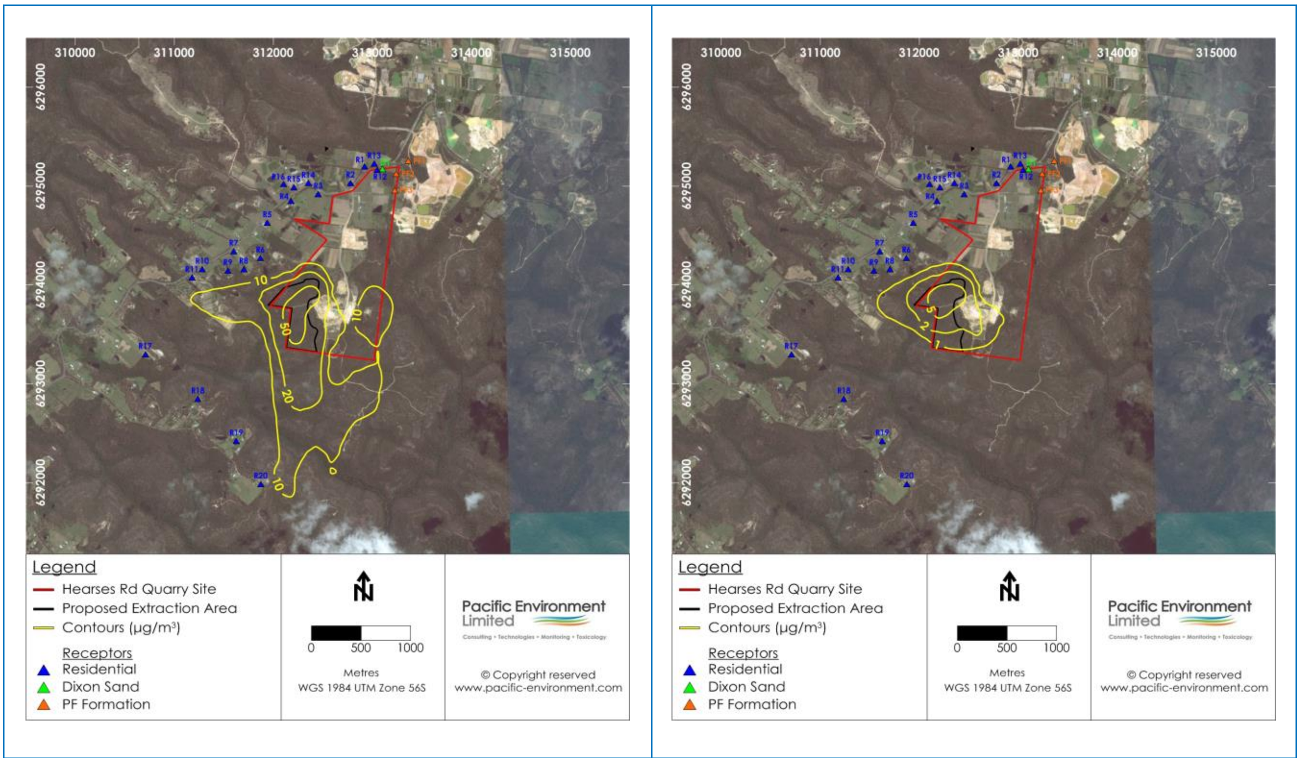
Contour plots for the predicted glcs of $PM_{2.5}$ are presented in **Figure 7.3** and **Figure 7.4**. There are no exceedances of the relevant 24-hour and annual average criteria beyond the site boundaries. There are no privately owned receivers that are predicted to experience glcs of $PM_{2.5}$ above the assessment criteria, due to emissions from the Modification only.

The highest predicted glc occurs at the receptor 6 (R6). At this location, the predicted incremental 24-hour $PM_{2.5}$ concentration is 5.7 $\mu g/m^3$ and the predicted annual average $PM_{2.5}$ concentration is 0.4 $\mu g/m^3$.



Annual Operations | Worst Case Day Operations

Figure 7.3: Maximum 24-Hour $PM_{2.5}$ Concentration – Scenario 1



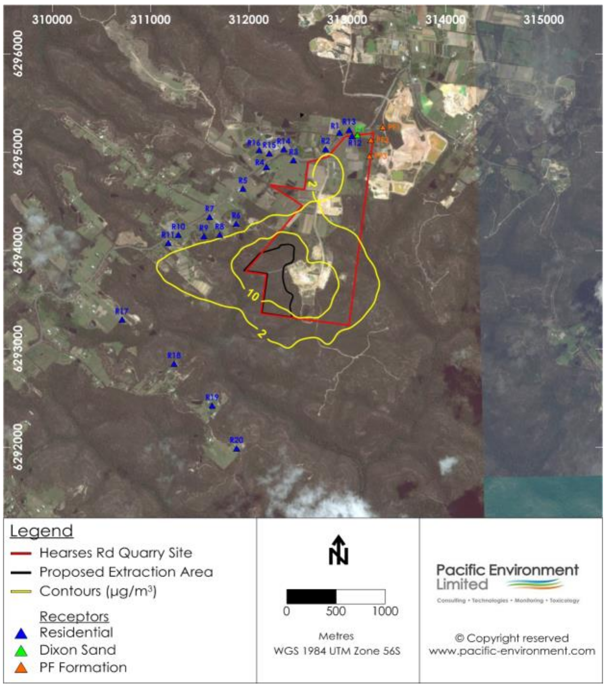
Annual Operations | Worst Case Day Operations

Figure 7.4: Incremental Annual Average $PM_{2.5}$ Concentration – Scenario 1

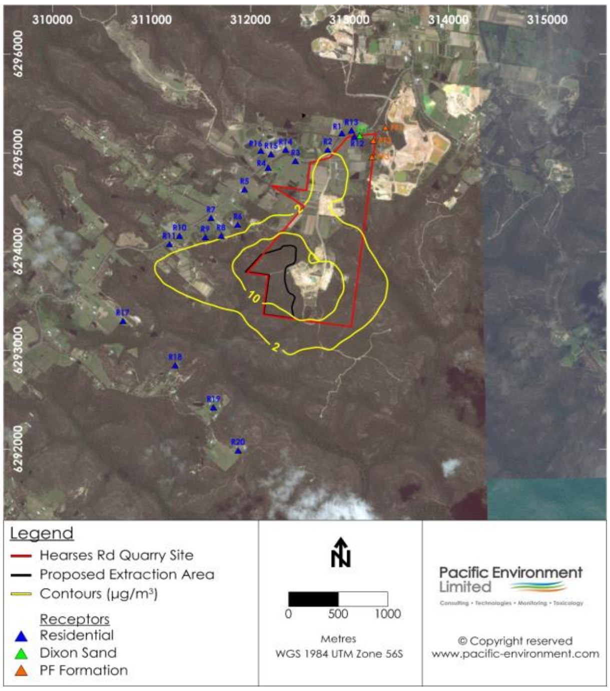
7.1.3 Ground Level TSP Concentrations

Contour plots for the predicted glcs of TSP are presented in **Figure 7.5**. There are no privately owned receptors that are predicted to experience glcs of TSP above the assessment criteria, due to emissions from the Modification only.

The highest predicted glc occurs at receptor 8 (R8). At this location, the predicted incremental annual average TSP concentration at this residence is 1.5 µg/m^3.



Annual Operations



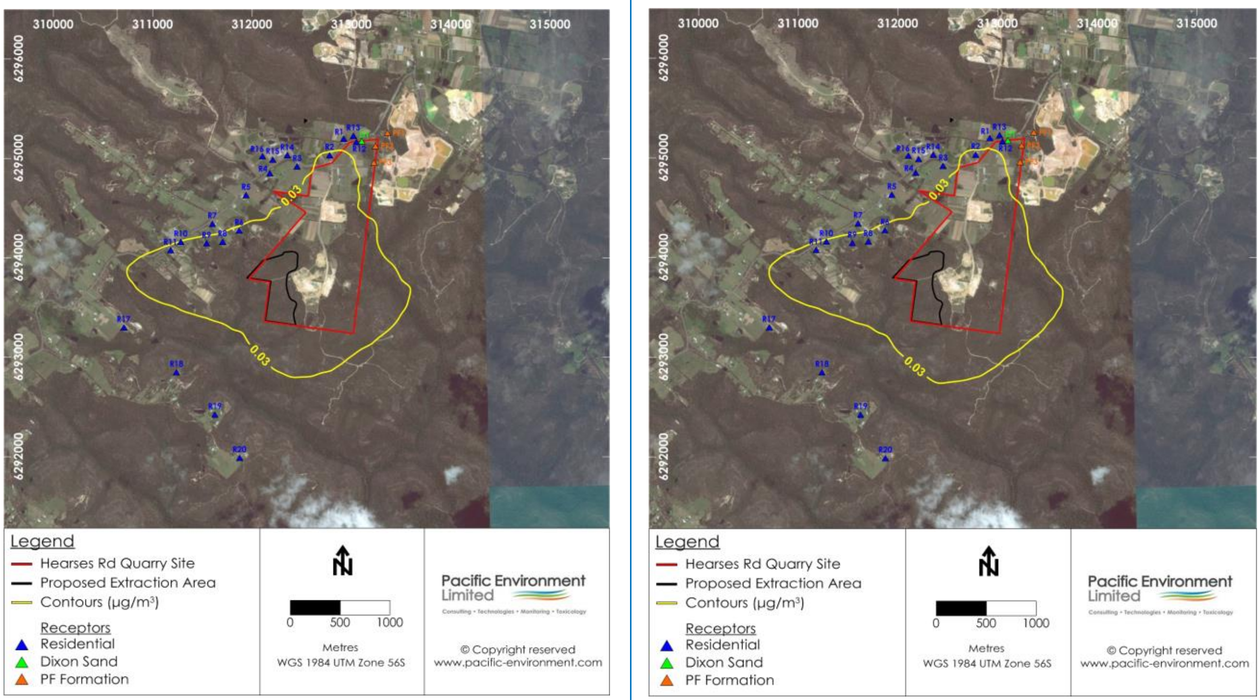
Worst Case Day Operations

Figure 7.5: Incremental Annual Average TSP Concentration – Scenario 1

7.1.4 Ground Level Dust Deposition Concentrations

Contour plots for the predicted glcs of dust deposition are presented in **Figure 7.6**. There are no privately owned receivers that are predicted to experience glcs of dust deposition above the assessment criteria, due to emissions from the Modification only.

The highest predicted glc occurs at receptor 8. At these locations, the predicted incremental annual average dust deposition concentrations is 0.05 g/m²/month.



Annual Operations	Worst Case Day Operations

Figure 7.6: Incremental Annual Average Dust Deposition Concentration – Scenario 1

7.2 Cumulative Impact Assessment

For 24-hour average concentrations, the cumulative concentrations are assumed to be the sum of the 24-hour average Maroota Public School data for PM_{10} and NSW EPA Wyong and Richmond data for $PM_{2.5}$, with the modelled contribution due to the Modification.

The assessment has been conservatively completed for the worst case day operations at the four most impacted receivers as a result of the Modification (R6, R10, R11 and, and R20).

For background annual average concentrations, the assumptions detailed in **Section 5.3** have been applied.

7.2.1 24-Hour average PM_{10}

The cumulative assessments of PM_{10} concentrations at the most impacted receptors are shown in **Figure 7.7**. The plots show the cumulative 24-hour average PM_{10} concentration compared with the assumed background over the 2015 period.

The results indicate that for all four receptors assessed there is potential for maximum of four additional exceedance of the cumulative 24-hour PM_{10} impact assessment criteria of 50 µg/m³.

R1 is the most impacted, with the Modification predicted to result in an additional four exceedances. However the percentage of time when the incremental concentration at R11 is over 2 µg/m³ is less than 1% of the modelled period, highlighting the relative minor impact of the Modification on the existing background particulate matter in the area. Therefore it is considered that only under worst case meteorological conditions combined with high background concentrations of particulate matter will an exceedance of the criteria potentially occur.

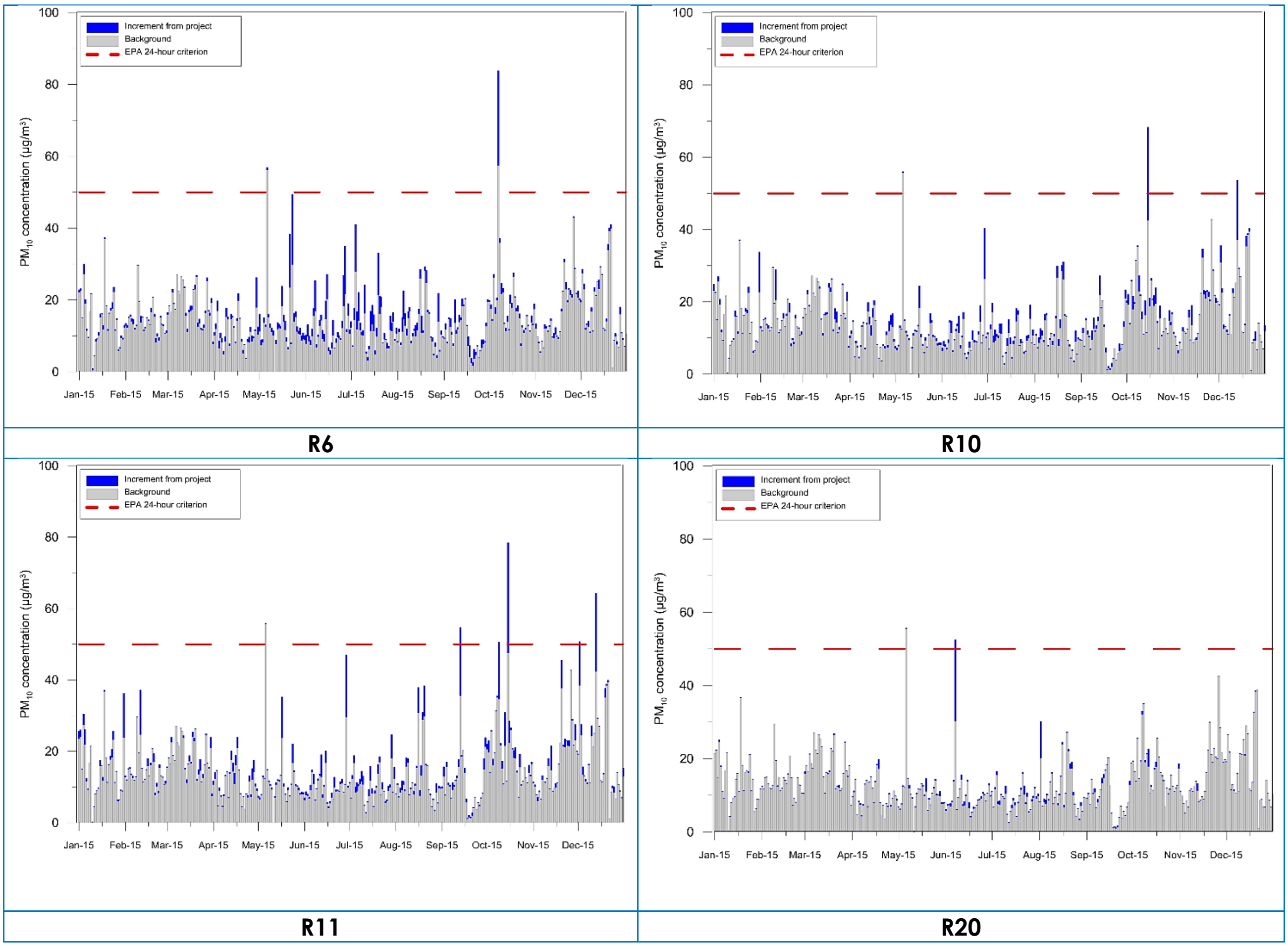


Figure 7.7: PM_{10} Concentration time-series – Scenario 1 (Worst Day Operations)

7.2.2 24-Hour average $PM_{2.5}$

The cumulative assessments of $PM_{2.5}$ concentrations at the most impacted receptors are shown in **Figure 7.8**. The plots show the cumulative 24-hour average $PM_{2.5}$ concentration compared with the assumed background over the 2015 period.

It is clear from these plots that the addition of the Modification would be unlikely to result in any days over the impact assessment criteria at the 25 µg/m³ level, and that the Modification has a very minimal impact on current $PM_{2.5}$ concentrations. It is noted that receptor 18 has been predicted to have one exceedance over the 2015 period, however this correlates with the highest background concentration and incremental increase, and hence the air quality impact is considered minor.

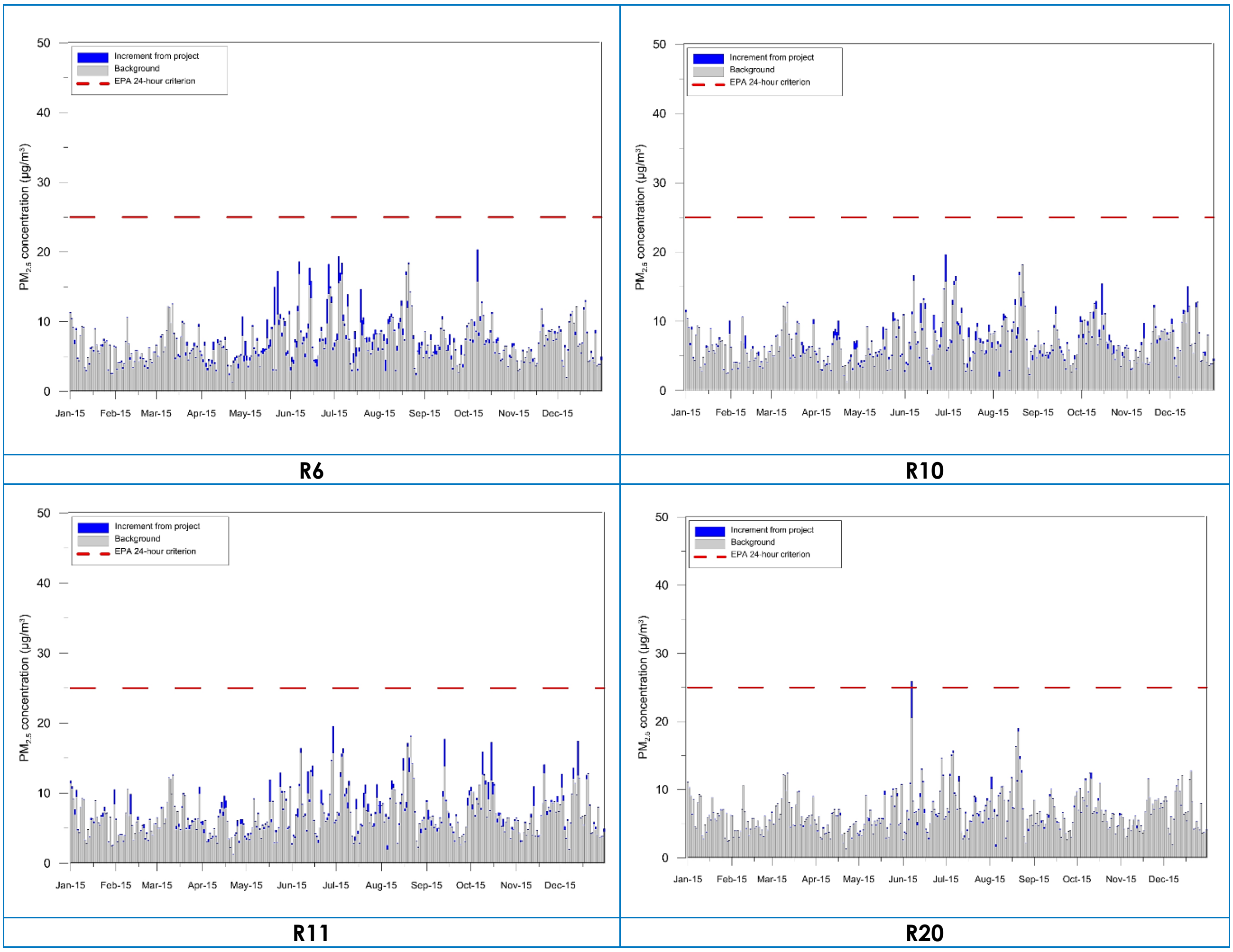


Figure 7.8: $PM_{2.5}$ Concentration time-series – Scenario 1 (Worst Day Operations)

8 CONCLUSION

Pacific Environment has completed an air quality assessment for Dixon Sand for the proposed Modification of the existing sand quarry at the Haerses Road site in Maroota NSW.

The operational stage has been modelled for average annual production. A worst case 24-hour operational scenario has also been modelled accounting for maximum daily throughput. Two scenarios were assessed to account for dry processing activities that could occur in different locations on site.

The results of the modelling indicate that the predicted incremental PM_{10}, $PM_{2.5}$, TSP and dust deposition at the closest sensitive receivers all comply with the impact assessment criteria.

A cumulative assessment, incorporating existing background levels, indicates that the Modification may result in some additional exceedances of relevant impact assessment criteria at the closest sensitive receptors, if the worst day operations happened to coincide with already elevated background concentrations. However this outcome is considered unlikely to occur and the current requirements to modify/cease operations if rolling 24-hour averages exceed 42 $\mu g/m^3$ will minimise the potential for this to occur even further.

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Appendix A MODEL SET UP

Table B.1: AERMOD setup Options used

AERMOD				
Meteorology				
Meteorological data for Surface Files –(Samson file)	Maroota Public School - Meteorological Station • Air temperature • Relative Humidity • Wind speed • Wind direction • Station Pressure • Precipitation TAPM centred over Maroota Public School • Cloud cover • Cloud height			
Land Use	Cultivated land (Albedo – 0.28, Bowen ratio- 0.75 and Surface roughness – 0.0725)			
AERMET PFL	Upper Air estimator			
Year of analysis	January 2015 - December 2015			
Model Set up				
Centre of domain (lat, long)	-33°28.16' S, 150°59.35' E			
Centre of domain (easting, northing)	313500, 6294672			
MGA coordinate zone	56 S			
Grid domain size	5km x 5km			
Grid spacing	200m			
South west corner of gridded receiver domain (m)	308800, 6290300			
Number of grid points	40 x 40			
Terrain data	SRTM3 at 90m resolution			
Rural Mode	Selected			
Particle parameters				
Particle type	TSP	PM_{10}	$PM_{2.5}$	Dust deposition
Particle Method	Method 1	Method 1	Method 1	Selected
Particle diameter (microns)	17	5	1	17
Mass Fraction	1	1	1	1
Particle Density	N/A	N/A	N/A	2.5
Dry depletion	Selected	Selected	Selected	Selected
Output Options				
Highest values				

Appendix B EMISSION ESTIMATES

B.1 EMISSION ESTIMATES

Silt and moisture content

Silt and moisture content values for in quarry activities are based on measured values provided by Dixon Sand operations.

	Silt content (%)	Moisture content (%)
Topsoil	13	4
Product	13	10
Hauling - unsealed	6.4	N/A

Loading / transfer material dumping

Each tonne of material loaded will generate a quantity of particulate matter that will depend on the wind speed and the moisture content according to the US EPA emission factor equation (**US EPA, 1985 and updates**) shown below:

$$E\ (kg/t) = k\ \times 0.0016\ \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \right)$$

Where:

K = 0.74 for TSP, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$

U – wind speed (m/s)

M – moisture content (%)

The moisture content of the raw material is assumed to be 4%, the processed material is assumed to be 10% and the wind speed is taken from the wind speed data from Maroota Public School Meteorological monitor.

Hauling material on unsealed surfaces

The emission estimate of wheel generated dust associated with hauling at the quarry (i.e. for hauling of material during construction is based the US EPA AP42 emission equation for unpaved surfaces at industrial sites (**US EPA, 1985 and updates**) shown below:

$$E_{TSP}\ (kg/VKT) = 0.2819 \times 4.9 \times [\ (s/12)\text{^}0.7 \times ((W \times 1.1023)/3)\text{^}0.45]$$

$$E_{PM_{10}}\ (kg/VKT) = 0.2819 \times 1.5 \times [\ (s/12)\text{^}0.9 \times ((W \times 1.1023)/3)\text{^}0.45]$$

$$E_{PM_{2.5}}\ (kg/VKT) = 0.2819 \times 0.15 \times [\ (s/12)\text{^}0.9 \times ((W \times 1.1023)/3)\text{^}0.45]$$

Where:

s = silt content of road surface
W = mean vehicle weight
The silt content (s) for the haulage routes is assumed to be 6.4%.

The mean vehicle weight used in the emissions estimates is an average of the loaded and unloaded gross vehicle mass, to account for one empty trip and one loaded trip.

Client supplied	Vehicle type	Unloaded (tare) weight	Loaded (GVM) including load	Capacity (tonnes)
Onsite	Dump Truck	23	51	28
Onsite	Product Truck	15	45	30

Hauling material on sealed surfaces

The emission estimate of wheel generated dust associated with hauling from the site towards the processing plant is based the US EPA AP42 emission equation for paved roads at (**US EPA, 1985 and updates**) shown below:

$$E_{TSP}\ (kg/VKT) = k \times [\ (sL)\text{^}0.91 \times (W)\text{^}1.02]$$

Where:

k = 3.23 for TSP, 0.62 for PM_{10} and 0.15 for $PM_{2.5}$ in g/VKT

sL = road surface silt loading

W = mean vehicle weight

The silt content (s) for the haulage routes is assumed to be 0.4g/m^2.

Dozers

Emissions from dozers have been calculated using the US EPA emission factor equation (**US EPA, 1985 and updates**).

$$E_{TSP}(kg/hr) = 2.6\ \times \frac{s^{1.2}}{M^{1.3}}$$

$$E_{PM_{10}}(kg/hr) = \ 0.3375 \times \frac{s^{1.5}}{M^{1.4}}$$

$$E_{PM_{2.5}}(kg/hr) = \ 0.105 \times E_{TSP}$$

Where:

s = silt content (assumed to be 13%)

M = moisture content (assumed to be 4% for topsoil and 10% for sand product).

Wind Erosion

The emission factor used for wind erosion has been taken as 0.1 kg/ha for TSP and 0.05 kg/ha for PM_{10} and 0.075 kg/ha for $PM_{2.5}$ **US EPA (1985 and updates)**.

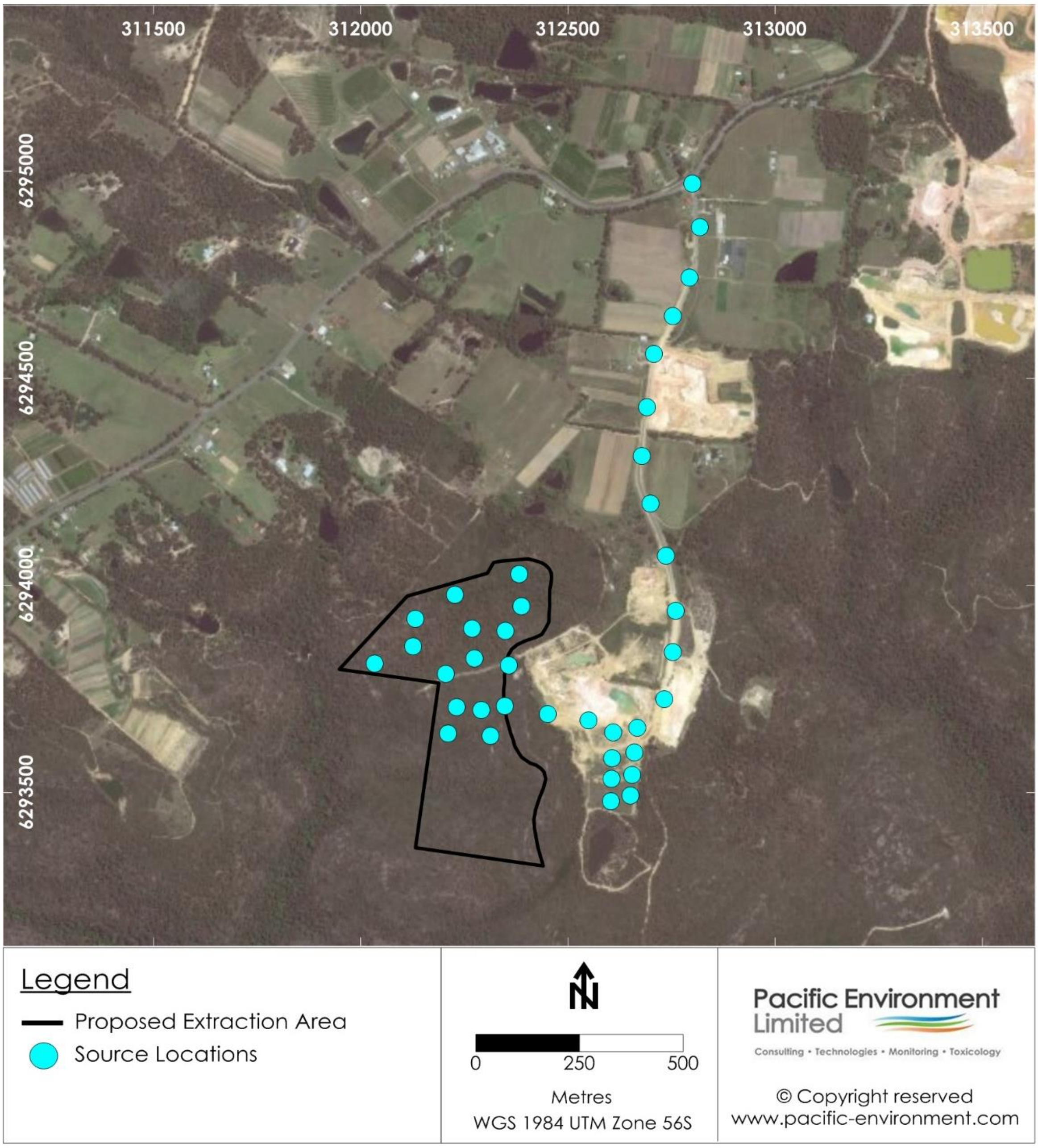

Figure B.1: Source Locations

General Operations - TSP

ACTIVITY	TSP (kg/y)	Intensity	Units	Emission factor	Units	Variable 1	Units	Variable	Units	Variable 3	Units	Variable 3	Units	Variable 4	Units	Control	Units	Type
Extraction Area																		
Dozer stripping topsoil (from pit 5)	9,312	1,000	h/y	9.3	kg/h	13	silt content in %	4	moisture content (%)									1
FEL Loading sand to trucks (from pit 5)	53	250000	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Hauling from pit 5 to Processing Area (unsealed)	7,423	250000	t/y	0.119	kg/t	28	t/load	51	Vehicle gross mass (t)	1	km/return trip	3.33	kg/VKT	6.4	% silt content	75	% control	1
Processing Area																		
FEL Unloading sand to stockpile	53	250,000	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Loading sand from stockpile	53	250,000	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Unloading sand to Dry Processing	53	250,000	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Crusher (uncontrolled)	4,875	250,000	t/y	0.0195	kg/t													1
Transfer (Crusher to Screen) [conveyor transfer point]	53	250,000	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Screen (uncontrolled)	3,125	250,000	t/y	0.0125	kg/t													1
Transfer (Screen to Wet Processing) [conveyor transfer point]	53	250,000	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Wet Processing (no expected emissions)	-																	1
FEL Loading sand from Product Stockpile to haul trucks	15	250,000	t/y	0.00006	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	10	moisture content (%)									2
Hauling out of Site (unsealed)	7,204	250,000	t/y	0.115	kg/t	30	t/load	45	Vehicle gross mass (t)	1.1	km/return trip	3.14	kg/VKT	6.4	% silt content	75	% control	1
Hauling out of Site (sealed)	1,630	250,000	t/y	0.007	kg/t	30	t/load	45	Vehicle gross mass (t)	2.6	km/return trip	0.08	kg/VKT	0.4	g/m2 silt loading	0	% control	1
Wind Erosion																		
WE - Extraction Area (pit 3)	2,628	3.0	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - (pit 4)	4,380	5.0	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - (pit 5)	4,468	5.1	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - Extraction Stockpile	123	0.14	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - Pre Processing Stockpile	123	0.14	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - Product Stockpile	123	0.14	ha	0.1	kg/ha/h	8,760	h									0	% control	3
TOTAL EMISSIONS	**45,743**																	

General Operations – PM_{10}

ACTIVITY	PM10 (kg/y)	Intensity	Units	Emission factor	Units	Variable 1	Units	Variable	Units	Variable 3	Units	Variable 3	Units	Variable 4	Units	Control	Units	Type
Extraction Area																		
Dozer stripping topsoil (from pit 5)	2,271	1,000	h/y	2.3	kg/h	13	silt content in %	4	moisture content (%)									1
FEL Loading sand to trucks (from pit 5)	25	250000	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Hauling from pit 5 to Processing Area (unsealed)	2,004	250000	t/y	0.032	kg/t	28	t/load	51	Vehicle gross mass (t)	1	km/return trip	0.90	kg/VKT	6.4	% silt content	75	% control	1
Processing Area																		
FEL Unloading sand to stockpile	25	250,000	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Loading sand from stockpile	25	250,000	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Unloading sand to Dry Processing	25	250,000	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Crusher (uncontrolled)	1,875	250,000	t/y	0.0075	kg/t													1
Transfer (Crusher to Screen) [conveyor transfer point]	25	250,000	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Screen (uncontrolled)	1,075	250,000	t/y	0.0043	kg/t													1
Transfer (Screen to Wet Processing) [conveyor transfer point]	25	250,000	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Wet Processing (no expected emissions)	-																	1
FEL Loading sand from Product Stockpile to haul trucks	7	250,000	t/y	0.00003	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	10	moisture content (%)									2
Hauling out of Site (unsealed)	1,945	250,000	t/y	0.031	kg/t	30	t/load	45	Vehicle gross mass (t)	1.1	km/return trip	0.85	kg/VKT	6.4	% silt content	75	% control	1
Hauling out of Site (sealed)	313	250,000	t/y	0.001	kg/t	30	t/load	45	Vehicle gross mass (t)	2.6	km/return trip	0.01	kg/VKT	0.4	g/m2 silt loading	0	% control	1
Wind Erosion																		
WE - Extraction Area (pit 3)	1,314	3.0	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - (pit 4)	2,190	5.0	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - (pit 5)	2,234	5.1	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - Extraction Stockpile	61	0.14	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - Pre Processing Stockpile	61	0.14	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - Product Stockpile	61	0.14	ha	0.05	kg/ha/h	8,760	h									0	% control	3
TOTAL EMISSIONS	**15,561**																	

General Operations - $PM_{2.5}$

ACTIVITY	PM2.5 (kg/y)	Intensity	Units	Emission factor	Units	Variable 1	Units	Variable	Units	Variable 3	Units	Variable 3	Units	Variable 4	Units	Control	Units	Type
Extraction Area																		
Dozer stripping topsoil (from pit 5)	978	1,000	h/y	0.98	kg/h	13	silt content in %	4	moisture content (%)									1
FEL Loading sand to trucks (from pit 5)	4	250000	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Hauling from pit 5 to Processing Area (unsealed)	200	250000	t/y	0.003	kg/t	28	t/load	51	Vehicle gross mass (t)	1	km/return trip	0.09	kg/VKT	6.4	% silt content	75	% control	1
Processing Area																		
FEL Unloading sand to stockpile	4	250,000	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Loading sand from stockpile	4	250,000	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Unloading sand to Dry Processing	4	250,000	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Crusher (controlled)	146	250,000	t/y	0.00059	kg/t													1
Transfer (Crusher to Screen) [conveyor transfer point]	4	250,000	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Screen (controlled)	94	250,000	t/y	0.00038	kg/t													1
Transfer (Screen to Wet Processing) [conveyor transfer point]	4	250,000	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Wet Processing (no expected emissions)	-																	1
FEL Loading sand from Product Stockpile to haul trucks	1	250,000	t/y	0.000004	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	10	moisture content (%)									2
Hauling out of Site (unsealed)	194	250,000	t/y	0.003	kg/t	30	t/load	45	Vehicle gross mass (t)	1.1	km/return trip	0.08	kg/VKT	6.4	% silt content	75	% control	1
Hauling out of Site (sealed)	76	250,000	t/y	0.000	kg/t	30	t/load	45	Vehicle gross mass (t)	2.6	km/return trip	0.00	kg/VKT	0.4	g/m2 silt loading	0	% control	1
Wind Erosion																		
WE - Extraction Area (pit 3)	197	3.0	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - (pit 4)	329	5.0	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - (pit 5)	335	5.1	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - Extraction Stockpile	9	0.14	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - Pre Processing Stockpile	9	0.14	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - Product Stockpile	9	0.14	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
TOTAL EMISSIONS	**2,600**																	

Worst Case Operations - TSP

ACTIVITY	TSP (kg/y)	Intensity	Units	Emission factor	Units	Variable 1	Units	Variable 2	Units	Variable 3	Units	Variable 3	Units	Variable 4	Units	Control	Units	Type
Extraction Area																		
Dozer stripping topsoil (from pit 5)	9,312	1,000	h/y	9.3	kg/h	13	silt content in %	4	moisture content (%)									1
FEL Loading sand to trucks (from pit 5)	65	310250	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Hauling from pit 5 to Processing Area (unsealed)	9,212	310250	t/y	0.119	kg/t	28	t/load	51	Vehicle gross mass (t)	1	km/return trip	3.33	kg/VKT	6.4	% silt content	75	% control	1
Processing Area																		
FEL Unloading sand to stockpile	65	310,250	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Loading sand from stockpile	65	310,250	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Unloading sand to Dry Processing	65	310,250	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Crusher (uncontrolled)	6,050	310,250	t/y	0.0195	kg/t													1
Transfer (Crusher to Screen) [conveyor transfer point]	65	310,250	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Screen (uncontrolled)	3,878	310,250	t/y	0.0125	kg/t													1
Transfer (Screen to Wet Processing) [conveyor transfer point]	65	310,250	t/y	0.00021	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Wet Processing (no expected emissions)	-																	1
FEL Loading sand from Product Stockpile to haul trucks	18	310,250	t/y	0.00006	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	10	moisture content (%)									2
Hauling out of Site (unsealed)	8,940	310,250	t/y	0.115	kg/t	30	t/load	45	Vehicle gross mass (t)	1.1	km/return trip	3.14	kg/VKT	6.4	% silt content	75	% control	1
Hauling out of Site (sealed)	2,023	310,250	t/y	0.007	kg/t	30	t/load	45	Vehicle gross mass (t)	2.6	km/return trip	0.08	kg/VKT	0.4	g/m2 silt loading	0	% control	1
Wind Erosion																		
WE - Extraction Area (pit 3)	2,628	3.0	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - (pit 4)	4,380	5.0	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - (pit 5)	4,468	5.1	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - Extraction Stockpile	123	0.14	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - Pre Processing Stockpile	123	0.14	ha	0.1	kg/ha/h	8,760	h									0	% control	3
WE - Product Stockpile	123	0.14	ha	0.1	kg/ha/h	8,760	h									0	% control	3
TOTAL EMISSIONS	**51,669**																	

Worst Case Operations - PM_{10}

ACTIVITY	PM10 (kg/y)	Intensity	Units	Emission factor	Units	Variable 1	Units	Variable	Units	Variable 3	Units	Variable 3	Units	Variable 4	Units	Control	Units	Type
Extraction Area																		
Dozer stripping topsoil (from pit 5)	2,271	1,000	h/y	2.3	kg/h	13	silt content in %	4	moisture content (%)									1
FEL Loading sand to trucks (from pit 5)	31	310250	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Hauling from pit 5 to Processing Area (unsealed)	2,487	310250	t/y	0.032	kg/t	28	t/load	51	Vehicle gross mass (t)	1	km/return trip	0.90	kg/VKT	6.4	% silt content	75	% control	1
Processing Area																		
FEL Unloading sand to stockpile	31	310,250	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Loading sand from stockpile	31	310,250	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Unloading sand to Dry Processing	31	310,250	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Crusher (uncontrolled)	2,327	310,250	t/y	0.0075	kg/t													1
Transfer (Crusher to Screen) [conveyor transfer point]	31	310,250	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Screen (uncontrolled)	1,334	310,250	t/y	0.0043	kg/t													1
Transfer (Screen to Wet Processing) [conveyor transfer point]	31	310,250	t/y	0.00010	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Wet Processing (no expected emissions)	-																	1
FEL Loading sand from Product Stockpile to haul trucks	9	310,250	t/y	0.00003	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	10	moisture content (%)									2
Hauling out of Site (unsealed)	2,413	310,250	t/y	0.031	kg/t	30	t/load	45	Vehicle gross mass (t)	1.1	km/return trip	0.85	kg/VKT	6.4	% silt content	75	% control	1
Hauling out of Site (sealed)	388	310,250	t/y	0.001	kg/t	30	t/load	45	Vehicle gross mass (t)	2.6	km/return trip	0.01	kg/VKT	0.4	g/m2 silt loading	0	% control	1
Wind Erosion																		
WE - Extraction Area (pit 3)	1,314	3.0	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - (pit 4)	2,190	5.0	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - (pit 5)	2,234	5.1	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - Extraction Stockpile	61	0.14	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - Pre Processing Stockpile	61	0.14	ha	0.05	kg/ha/h	8,760	h									0	% control	3
WE - Product Stockpile	61	0.14	ha	0.05	kg/ha/h	8,760	h									0	% control	3
TOTAL EMISSIONS	**17,337**																	

Worst Case Operations - $PM_{2.5}$

ACTIVITY	PM2.5 (kg/y)	Intensity	Units	Emission factor	Units	Variable 1	Units	Variable	Units	Variable 3	Units	Variable 3	Units	Variable 4	Units	Control	Units	Type
Extraction Area																		
Dozer stripping topsoil (from pit 5)	978	1,000	h/y	0.98	kg/h	13	silt content in %	4	moisture content (%)									1
FEL Loading sand to trucks (from pit 5)	5	310250	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Hauling from pit 5 to Processing Area (unsealed)	249	310250	t/y	0.003	kg/t	28	t/load	51	Vehicle gross mass (t)	1	km/return trip	0.09	kg/VKT	6.4	% silt content	75	% control	1
Processing Area																		
FEL Unloading sand to stockpile	5	310,250	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Loading sand from stockpile	5	310,250	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
FEL Unloading sand to Dry Processing	5	310,250	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Crusher (controlled)	181	310,250	t/y	0.00059	kg/t													1
Transfer (Crusher to Screen) [conveyor transfer point]	5	310,250	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Screen (controlled)	116	310,250	t/y	0.00038	kg/t													1
Transfer (Screen to Wet Processing) [conveyor transfer point]	5	310,250	t/y	0.000015	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	4	moisture content (%)									2
Wet Processing (no expected emissions)	-																	1
FEL Loading sand from Product Stockpile to haul trucks	1	310,250	t/y	0.000004	kg/t	0.47	average of (wind speed/2.2)^1.3 in m/s	10	moisture content (%)									2
Hauling out of Site (unsealed)	241	310,250	t/y	0.003	kg/t	30	t/load	45	Vehicle gross mass (t)	1.1	km/return trip	0.08	kg/VKT	6.4	% silt content	75	% control	1
Hauling out of Site (sealed)	94	310,250	t/y	0.000	kg/t	30	t/load	45	Vehicle gross mass (t)	2.6	km/return trip	0.00	kg/VKT	0.4	g/m2 silt loading	0	% control	1
Wind Erosion																		
WE - Extraction Area (pit 3)	197	3.0	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - (pit 4)	329	5.0	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - (pit 5)	335	5.1	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - Extraction Stockpile	9	0.14	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - Pre Processing Stockpile	9	0.14	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
WE - Product Stockpile	9	0.14	ha	0.0075	kg/ha/h	8,760	h									0	% control	3
TOTAL EMISSIONS	**2,777**																	

Appendix C MAROOTA PUBLIC SCHOOL WINDROSES

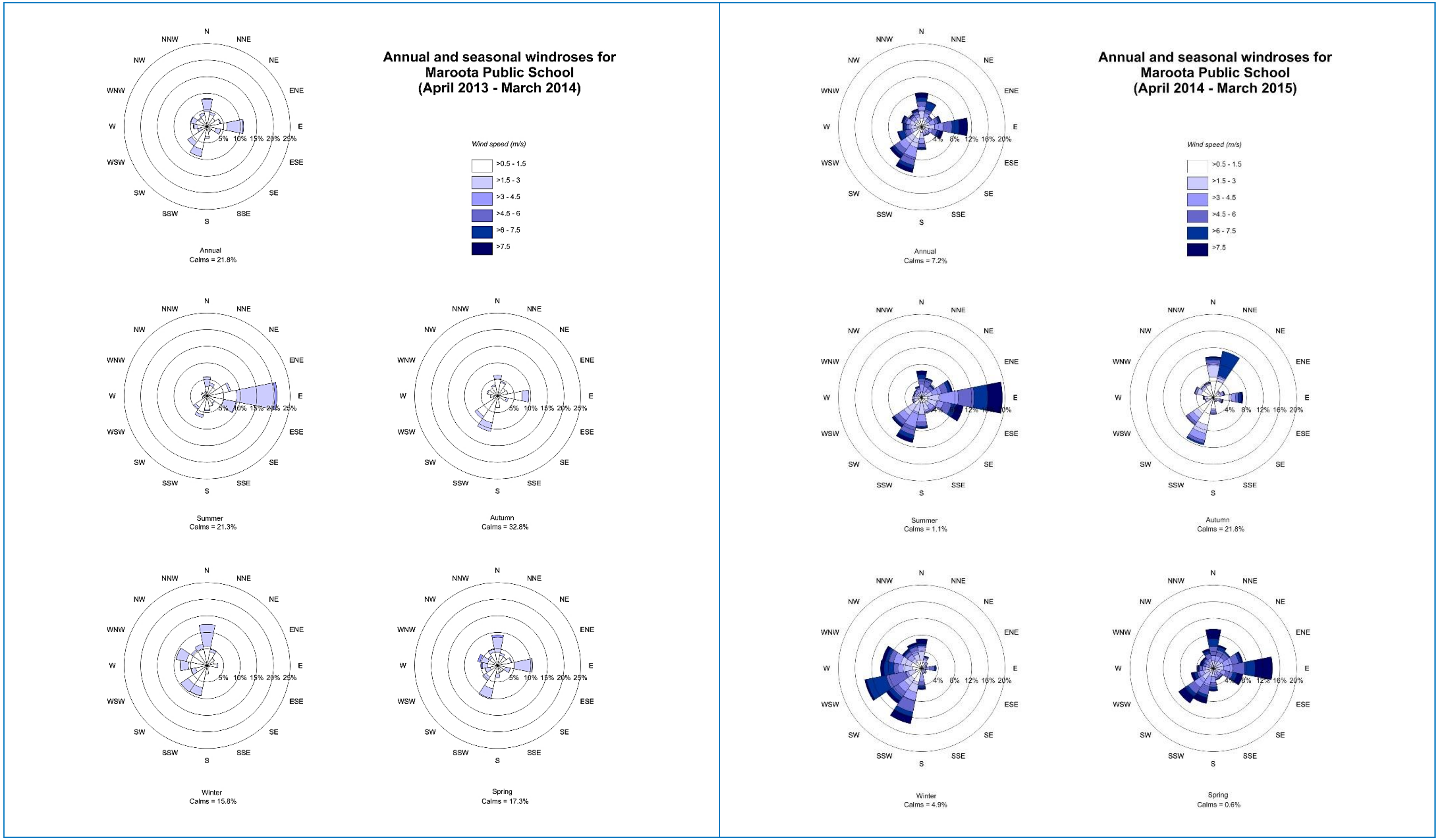

Figure C.1: Wind roses for Maroota Public School – (Left: April 2013 – March 2014, Right: April 2014 – March 2015)